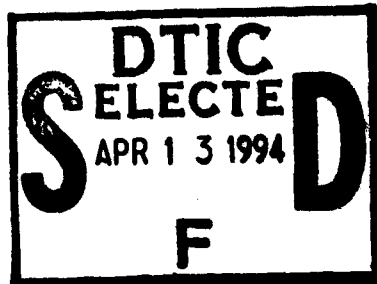


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13. ABSTRACT (Maximum 200 words) This report contains 357 summaries of research projects which were carried out under funding of the Naval Postgraduate School Research Program. A list of recent publications is also included which consists of conference presentations and publications, contributions to books, published papers, magazine articles, and technical reports. The research was conducted in the areas of Aeronautics and Astronautics, Computer Science, Electrical and Computer Engineering, Mathematics, Mechanical Engineering, Meteorology, National Security Affairs, Oceanography, Operations Research, Physics and Systems Management. <div style="text-align: right;">DTIC QUALITY INSPECTED 8</div>				
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THE NAVAL POSTGRADUATE SCHOOL MISSION

The mission of the Naval Postgraduate School is to provide advanced professional studies at the graduate level for military officers and defense officials from all services and other nations. The School's focus is to increase the combat effectiveness of the armed forces of the United States by providing quality education which supports the unique needs of the defense establishment.

PREFACE

The Naval Postgraduate School Research Program follows from the School's mission "... to increase the combat effectiveness of the armed forces of the United States by providing quality education ...". Quality education requires that the School foster a program of research to sustain academic excellence. The NPS Research Program is guided by the Research Office in accordance with the Research Office mission statement:

- o To develop an overall research investment strategy that ensures a high quality, creative learning experience for NPS graduate students
- o To encourage pursuit of new discoveries and applications which enhance the long term effectiveness of the armed forces
- o To stimulate interactions between NPS faculty and a wide variety of potential research sponsors
- o To publicize (both internally and externally) significant achievements of the NPS research program

The overall program consists of two parts, the Direct Funded Research Program and the Reimbursable Research Program. The Direct Funded Research Program provides internal funding for (1) the Research Initiation Program for new faculty, (2) Navy relevant, meritorious research, (3) interdisciplinary research, (4) unique facilities of institutional importance, and (5) postdoctoral programs. The Reimbursable Research Program consists of those projects which have been funded by outside agencies on the basis of proposals submitted by NPS faculty. In all cases we expect that research pursued at NPS should provide creative, relevant thesis opportunities for our students. The two programs are complementary and ensure that the overall research program is flexible, responsive, balanced and supportive of the School's curricula.

In 1993, the faculty executed 124 research work-years. Of this total, 73% were reimbursable and 27% were direct funded. The work was 63% Navy and 37% non-Navy. The funding received for reimbursable research totaled approximately \$27M, including carryover from FY 92, and was almost equally divided between Navy and non-Navy sponsors. The research work resulted in 815 theses, 200 journal papers, 505 conference presentations, 103 technical reports, 54 books and chapters, and 1 patent. In addition, NPS faculty received various national and international awards in recognition of their research accomplishments.

Research at NPS is carried out by faculty in the School's 11 Academic Departments and 4 Academic Groups. In the pages that follow, Research Summaries are provided for projects conducted by the faculty during FY 1993. They are grouped by Department and Academic Group with an overview provided by the Department or Group Chair. A List of Publications for each Academic Department is also included. At the back of this book there is a Key Technology Index in which all projects are listed. In this Index, projects have been placed under one or more of the 11 key technology areas identified by the Department of Defense or listed as "Other".

Questions about particular projects may be directed to the principal investigator or to the Research Office. General questions about the NPS Research Program should be directed to the Research Office at (408) 656-2098 (voice), (408) 656-2038 (FAX) or research@nps.navy.mil (internet).

A companion volume, "Compilation of Abstracts of Theses Submitted by Candidates for Degrees" contains abstracts of approximately 800 unclassified theses completed by NPS graduate students, and is also published yearly.

May 1994

Jeffrey B. Knorr
Associate Dean
of Research

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Chairman**

DEPARTMENT OF AERONAUTICS AND ASTRONAUTICS

The research program in the Department of Aeronautics and Astronautics is the product of the activities of the Department's five technical groups; namely, Aerodynamics, Structures, Propulsion, Flight Mechanics and Controls, and System Design (both air and spacecraft). Within, and across, these technical disciplines, the research effort is focused on topics of critical importance to Navy and other military weapons systems. With the exception of one project undertaken by Professor Howard for Naval Air Systems Command, to conduct a computer analysis and produce a training video showing the potential hazards of formation flying from aerodynamic interference effects, the Department's research activities are concentrated in the following areas:

F18, X31, HIGH-ALPHA AERODYNAMICS & ENHANCED AIRCRAFT MANEUVERABILITY STUDIES

Initiated concurrently with the Navy's X31 research aircraft project, a collaborative effort by Professors Platzer, Chandrasekhara, Ekaterinaris and Hebbar is underway to investigate the flow behavior around current and proposed fighter configurations during high angle of attack maneuvers and to identify promising methods for the generation and exploitation of dynamic lift. The effort involves both experimental and advanced computational (CFD) tasks conducted at NPS and at NASA Ames Research Center through the auspices of the NPS-Ames Joint Institute. Low speed wind and water tunnel studies have been carried out at NPS with an X-31A-like fighter model (with and without oscillating canards), double delta and YF-17 aircraft models. The latter study complimented full-scale F/A-18 tests in the Ames 80x120 ft. wind tunnel. Experiments to establish compressibility effects of dynamic stall are conducted at Ames. Also at Ames, exploratory experiments have been carried out to develop practical adaptive-geometry techniques for controlling unsteady separated flows. Methods to predict the complex flow structures and resulting unsteady forces and moments are under development using both Navier-Stokes and Viscous-Inviscid Interaction approaches. The flow physics of multi-element airfoils in unsteady motion are also being examined for possible applications in air vehicles. In a separate effort carried out at NPS by Professor Howard, a wind tunnel investigation of wing-and-strake blowing to control vortices produced by advanced maneuverable fighter configurations at high angles of attack, has been undertaken. This follows a previous study of canard-vortex/wing vortex interactions to explain the underlying mechanism for achieving enhanced lift.

HIGH-ANGLE-OF-ATTACK MISSILE AERODYNAMICS

In support of the Naval Air Warfare Center, Weapons Division, Professors Platzer and Ekaterinaris are developing Navier-Stokes solutions for turbulent flow over missile configurations in steady and unsteady high angle of attack flight at subsonic, transonic, and supersonic Mach numbers.

TOPICS RELATED TO ADVANCED ROTORCRAFT

A program led by Professor Wood has four areas. First, research is being conducted in the unsteady aerodynamics related to higher harmonic control (HHC). HHC is an active control system concept which promises reduced helicopter vibrations, lower rotor noise levels and improved helicopter performance. Recent NPS research based on the results from the 1984 NASA/Army/McDonnell Douglas OH-6A HHC flight test program show that a reduction in rotor power results due to the unsteady wake shed by the rotor with HHC turned on. Second, research is being conducted on the no tail rotor (NOTOR) concept which uses circulation control aerodynamics (coanda) effect to counter the torque from the helicopter's main rotor. This research is being carried out using: (1) a 1/4 scale remotely piloted helicopter with a NOTAR tailboom; (2) the NPS water tunnel; and (3) the NPS wind tunnel. Third, real-time flight simulation is being carried out for both helicopters and UAV's using FLIGHTLAB, which is a unique computer software program developed by Advanced Rotorcraft Technology that permits detailed modelling of aircraft to a level never before considered possible including many higher order and non-linear effects. Fourth, NPS is supporting NRL in a space-related program where the potential of rotor systems for retrieval of space payloads is being investigated. In a separate study, aimed at the "stall flutter" problem, Professors Chandrasekhara and Platzer are conducting unique experiments to examine the effects of compressibility on the dynamic stall of oscillating airfoils with a view to eventually controlling the stall of the retreating blade.

UNMANNED AIR VEHICLE (UAV) TECHNOLOGY

In support of the DoD's role in the development of UAV's, Professor Howard has developed a UAV laboratory at NPS which now contains various vehicles for flight or wind tunnel tests. The broad goal is to develop technologies and techniques applicable to UAV's, including Maritime, Close-Range, and Vertical Takeoff & Landing (VTOL) types. A year ago, the design, construction and testing of a full-scale VTOL UAV was initiated. Current focus, jointly with Professor Kaminer, is on flight controls and stability augmentation for this unique vehicle configuration. The "Archytas" is a tailsitter design with ducted-fan propulsion that must transition to horizontal flight. A multi-input, multi-output controller has been designed and tested and hover tests are imminent.

IMPROVING AIR VEHICLE CONTROLS & MILITARY APPLICATIONS OF NEURAL NETWORKS

Tracking controllers for advanced air vehicles need to be robust. Professor Kaminer has begun a study of the application of H_2 and a synthesis of H_2 and H_∞ techniques to the design of such controllers. The development of a methodology to properly implement gain-scheduled controllers in the air vehicle system is identified as a primary goal. A second effort is to investigate the application of the sensor and actuator failure detection and isolation (FDI) techniques developed for automobiles to air vehicle systems. Also, the development of a differential GPS/INS navigation system for automatic aircraft landing is being initiated, and real-time hardware-in-the-loop simulation with 3D animation is

planned. Following work on the X29 controller, Professor Collins has extended his work on neural networks to two important Navy problems. In the first, neural networks are being developed to identify transient sonar signals. In the second, neural network technology is being applied to ionospheric modeling and to PMA operator training.

FAILURE AND LIFE PREDICTION FOR ADVANCED COMPOSITE AND AGING ALUMINUM VEHICLE STRUCTURES

Increased use of composites structures in all weapons platforms requires that there be developed reliable predictive methods for failure and probable structural life. Professor Wu has undertaken this fundamental problem using an analytical approach which separates fiber, matrix and interface mechanisms, and uses carefully controlled experiments to establish necessary statistical strength and life data. A unique new laboratory for composites has been established at NPS and the first successful research results have now been reported. Aircraft structural fatigue and fracture is being addressed by Professor Lindsey, who recently has conducted an extensive survey of the Naval Air Systems Command's Aircraft Structural Life Surveillance (ASLS) Program.

ADVANCED AIRCRAFT ENGINE AND MISSILE PROPULSION STUDIES

Currently in its second phase, the goals of the third phase of the (tri-service, government/industry) Integrated High Performance Turbine Engine Technology (IHPTET) Program can only be reached by achieving very significant performance and weight advances in each of the engine components. Advancing fan and compressor and turbine aerodynamics (to allow higher-blade loading) is the focus of the work of Professors Shreeve and Hobson at the Turbopropulsion Laboratory. The general approach is to use the laboratory's exceptional experimental facilities to validate CFD codes being developed for use in advanced design. The off-design and stalling behavior of controlled-diffusion compressor blading is being measured in a very large-scale subsonic cascade wind tunnel. The alleviation of shock boundary-interaction losses is being studied in a transonic blow-down wind tunnel model simulation of the flow through fan passages. The details of flow in the tip region of high speed turbines is to be studied using, as a tool, the Space-Shuttle Main-Engine fuel-pump turbine and an annular cascade. Two- and three-dimensional traversing Laser-Doppler Velocimeter (LDV) systems have been developed for velocity field mapping. The development of successful diagnostic techniques to resolve small-scale, three-dimensional effects near to walls is necessary to achieve the goals of this and the IHPTET program.

Professor Netzer's work at the Combustion Laboratory has two thrusts relating to missile propulsion. First, toward IR signature reduction, under Air Force sponsorship, a technique for evaluating the effects of rocket motor chamber conditions and fuel additives on the emissivity of the plume is being developed. The study involves experiments in which plume particle size and concentration measurements are made and plume radiation is compared with computational code predictions. Second, under Navy sponsorship, a number of advanced ramjet propulsion ideas are investigated experimentally. These include supersonic

combustion with solid fuels, ignition and plume characteristics with boron/boron carbide fuel, investigations relating to the combustion of metallized slurry fuels, optimization of combustor design for high performance and low-cost, combined-cycle motors which can be carried by an RPV. Also, Professors Biblarz and Netzer have carried out an evaluation of theoretical and experimental approaches used for the measurement of soot size and optical properties in gas turbine exhausts. The study resulted in a patent disclosure for a new, simple technique for measuring soot concentration in gas turbine exhaust plumes.

SPACECRAFT DESIGN, ATTITUDE CONTROL & MANEUVER

A variety of projects result from the importance of spacecraft in Naval operations. First, the FLTSATCOM at NPS enabled a joint experiment to be conducted in 1993 with the Naval Satellite Operation Center (NAVSOC) to test, and in the process successfully verify, NAVSOC telemetry and command software. Also, the development of a Spacecraft Robotics Simulator, involving two dual-link manipulators and a common payload, was completed. In spacecraft design, efforts, an Alternate Techsat Satellite was designed to specifications provided by the Strategic Defense Initiative Office and a New Asteroid Rendezvous Satellite design won second place in the AIAA Graduate Teams Space Design Competition. Professors Agrawal and Bang continue their research efforts related to improving altitude control of flexible spacecraft, combining analytical efforts with robotic experiments. Professor Ross's research is on optimizing trajectories and atmospheric maneuvers to effect orbital plane changes. He has also recently reviewed the problem of uncontrolled satellite reentry and impact prediction, which is of concern to the Air Force (AF) SPACELOM.

AIRCRAFT COMBAT SURVIVABILITY AND LETHALITY ASSESSMENT

Professor Ball originated the study of survivability at NPS nineteen years ago and has since provided technical support to NAVAIR and the Joint Technical Coordinating Group on Aircraft Survivability (JTTCG/AS) by writing a textbook in aircraft survivability by providing five day short and two day "shorter" courses and by conducting analytical studies on specific weapons systems. In 1993, 150 U.S. military offices, DOD and industry engineers attended the five day course in Monterey. The shorter two-day course was given at the Naval Air Warfare Center, Patuxent River, and at Newport News jointly for the US Army Aviation Systems Command and the US Air Force Air Combat Command. Analytical studies included an evaluation of the effects of pulsing the motor of an air-to-air missile on the miss distance from the target aircraft. Significant progress has been made in the development of the NPS/NAVAIR Survivability & Lethality Assessment Center (SLAC) which was initiated under NAVAIR sponsorship. Two major programs, ACES/PHOENIX and EADSIM were added. ACES/PHOENIX runs on the secure NPS Wargaming, Analysis and Research Laboratory computer system while EADSIM runs on the NPS Computer Center Visualization Laboratory workstations. Aerodynamic models for the F-14A and F-14B were constructed and added to the database of the ACES/PHOENIX software package in the course of a study carried out for the Naval Air Warfare Center, Weapons Division (Point Mugu). This study aims to develop a methodology that can be used to assess the enhanced survivability of an

aircraft due to susceptibility reduction concepts. The methodology is needed to assess the enhanced survivability of the F-14 A/B due to the 1991 Upgrade Program. Progress on the 2nd edition of the textbook, The Fundamentals of Aircraft Combat Survivability Analysis and Design, published by AIAA, consisted of scanning for first edition and editing for scanned text.

ATTITUDE CONTROL OF FLEXIBLE SPACECRAFT

B.N. Agrawal, Professor

H. Bang, Research Assistant Professor

Department of Aeronautics and Astronautics

Sponsor and Funding: Naval Postgraduate School

OBJECTIVE: The goal of this project was to develop improved control techniques for flexible spacecraft and space robotic and validate them by experimental tests. It was a continuing project.

SUMMARY: A new closed-loop switching function for on-off thruster firing is developed to provide a good attitude control performance in the presence of modeling errors for single-axis slew maneuver of a rigid spacecraft. The switching function also provides capability of a trade-off between slew maneuver time and fuel expenditure. The analytical simulations and experimental results demonstrate that the new switching function provides significant improvement in the slew maneuver performance. In the area of space robotic, Lyapunov method was used to develop cooperative control of multiple space manipulators. A fifth order polynomial reference trajectory was selected. The control torque consists of reference torque and a torque related to tracking errors and rates. The system consisted of two dual link manipulators with a common payload. The analytical and experimental results demonstrated good performances of the control laws.

PUBLICATIONS: Agrawal, B.N., "Dynamic Characteristics of Liquid

Motion in Partially Filled Tanks of a Spinning Spacecraft," AIAA Journal of Guidance, Control, and Dynamics, Vol. 16, No. 4, pp. 636-640, July-August, 1993.

Agrawal, B.N., "Attitude Control of Flexible Spacecraft," in Proceedings of the International Symposium on Advances in Aerospace Sciences and Engineering, Bangalore, India, 12-15 December 1992.

Agrawal, B.N. and Bang, H., "Slow Maneuver of a Flexible Spacecraft using On-Off Thrusters," in Proceedings of the AIAA Guidance, Navigation, and Control Conference, AIAA-93-3724, Monterey, CA, pp. 224-233, 9-11 August 1993.

CONFERENCE PRESENTATION: Agrawal, B.N., "Liquid Dynamics Characteristics in Spinning Spacecraft," International Conference on Computational Engineering Science (ICES'92), Hong Kong, 17-22 December 1992.

THESIS DIRECTED: Yale, G.E., CPT, USAF, "Cooperative Control of Multiple Space Manipulators," Ph.D. Dissertation, September 1993.

DOD KEY TECHNOLOGY AREA: Design Automation.

KEYWORDS: Flexible Spacecraft, Space Robotic, Slew Maneuver.

SPACECRAFT SYSTEMS

B.N. Agrawal, Professor

H. Bang, Research Assistant Professor

Department of Aeronautics and Astronautics

Sponsor and Funding: Space and Naval Warfare Systems Command

OBJECTIVE: To develop improved spacecraft system design techniques and continue development of spacecraft laboratories to perform research in spacecraft systems. In is a continuing project.

SUMMARY: A joint experiment with Naval Satellite Operation Center (NAVSOC) to test NAVSOC telemetry and command software by using the FLTSATCOM satellite at NPS. Commands and telemetry were sent between NAVSOC and NPS over telephone lines. The development of Spacecraft Robotics Simulator was completed. It consists of two dual-link manipulators with a common payload. Adaptive structures were developed using multiple piezoceramic sensors and actuators.

PUBLICATIONS: Agrawal, B.N., "High Latitude Communications Satellite," Navy Engineer Journal, July 1993.

Agrawal, B.N. and Bang, H., "Active

Vibration Control of Flexible Space Structures by using Piezoelectric Sensors and Actuators," in Proceedings of the 14th Biennial Conference on Mechanical Vibration and Noise, Albuquerque, NM, pp. 169-179, 19-22 September 1993.

THESES DIRECTED: Newman, S., LT, USN, "Active Damping Control of a Flexible Space Structure using Piezoelectric Sensors/Actuators," Master's Thesis, December 1992.

Hixenbaugh, F.D., LT, USN, "A Study on Piezoelectric Actuators and Sensors for Vibration Control of Flexible Space Structures," Master's Thesis, September 1993.

DOD KEY TECHNOLOGY AREA: Communications Networking.

KEYWORDS: FLTSATCOM, Telemetry and Command.

NASA/USRA ADVANCED DESIGN PROGRAM

B.N. Agrawal, Professor

Department of Aeronautics and Astronautics

Sponsor and Funding: University Space Research Association

OBJECTIVE: The goal is to promote engineering education in space and astronautics through design.

SUMMARY: Two spacecraft system design projects were completed; the Near Asteroid Rendezvous and NPS Alternate Techsat Satellite (NATSAT). The primary specifications for the Near Asteroid Rendezvous Satellite were based on an AIAA Lockheed Corporation Graduate Team Space Design Competition data package. The NPS design competition won second place in this national design competition. The objective of the NATSAT project was to design a spacecraft bus to support low earth orbit experiments. Specifications for the spacecraft bus were provided

by the Strategic Defense Initiative Office (SDIO).

CONFERENCE PRESENTATIONS: Agrawal, B.N., "Near-Earth Asteroid Rendezvous," Ninth Annual Summer Conference of the USRA Advanced Design Programs, Houston, Texas, 14-17 June 1993.

Agrawal, B.N., "NPS Alternate Techsat Satellite," Ninth Annual Summer Conference of the USRA Advanced Design Program, Houston, Texas, 14-27 June 1993.

DOD KEY TECHNOLOGY AREA: Design Automation.

KEYWORDS: Spacecraft, Small Satellites, Near-Earth Asteroid.

NPS SURVIVABILITY SUPPORT

R.E. Ball, Professor

Department of Aeronautics and Astronautics

**Sponsor and Funding: Joint Technical Coordinating Group on
Aircraft Survivability (JTCG/AS)**

OBJECTIVE: The objective of this effort is to continue the technical support provided to the JTCG/AS for the past 20 years by conducting research, presenting short courses, developing educational material, and performing analyses in aircraft combat survivability. The accomplishments during FY 93 are given below.

SUMMARY: (1) Short and Shorter Courses: Since 1979, the one week NPS/NAVAIR/JTCG/AS short course has been offered biennially by Prof. Ball. The most recent offering was in Monterey in April, 1993, and over 150 US military officers and DoD and US aerospace engineers and managers attended. In order to make the material available to more people, Prof. Ball developed an 18 hour shorter version of the one week course in 1991. In 1993, he conducted two shorter courses, one for the US Army Aviation Systems Command Aviation Applied Technology Directorate and the US Air Force Air Combat Command at Newport News and one for the Naval Air Test Center at Patuxent River. Approximately 45 students attended each course. (2) Educational Materials: Professor Ball continued the development of the second edition of his AIAA textbook, The Fundamentals of Aircraft Combat Survivability Analysis and Design. Progress in FY93 consisted of the completion of the scanning of the

first edition of the text and the editing of the scanned version, which consisted of correcting errors in the scanning, eliminating end of line characters, proper formatting, etc.

(3) Projects: Two thesis projects were completed in FY93. The first consisted of major improvements to the Macintosh-based program MACSAP. MACSAP is used to assess the payoffs and penalties associated with survivability enhancement features in the conceptual design phase. It has been distributed to over 30 organizations. The second consisted of a study of the effects of pulsing the motor of an air-to-air missile on the missile miss distance from the target aircraft.

THESES DIRECTED: Lindsay, C.S., LT, USN, "MACSAP 2.0: An Improved Version of the Macintosh Survivability Assessment Program," Master's Thesis, June 1993.

Dobrei, A.J., CPT, Canadian AF, "A Kinematic Upgrade to an Infrared Air-to-Air Missile Using Dual Interrupted-Thrust Technology and its Effect on Lethality," Master's Thesis, June 1993.

DOD KEY TECHNOLOGY AREA: Design Automation.

KEYWORDS: Aircraft, Survivability, Missile, Lethality, Modeling, Simulation.

NPS/NAVAIR SURVIVABILITY & LETHALITY ASSESSMENT CENTER

R.E. Ball, Professor

Department of Aeronautics and Astronautics

Sponsor and Funding: Naval Air Systems Command, Code 5164

OBJECTIVE: The objectives of this research project are (1) to develop a survivability and lethality assessment center within the NPS Wargaming Analysis & Research Laboratory, and (2) to use the center to conduct survivability and lethality studies. The computer programs in the center are available to the students and faculty at NPS for research in specific survivability and lethality topics on land, sea, air, and space targets as well as research on the programs themselves. The following efforts were completed or are still underway at the end of 1993.

SUMMARY: Two major programs were added to the SLAC; ACES/PHOENIX and EADSIM. (1) ACES/PHOENIX: This program was developed first by BDM and later by PRC to assess the survivability of friendly aircraft over hostile territory, particularly the survivability of the B-2 strategic bomber. It is a shell program that combines several existing classified programs for the survivability analysis of aircraft into one program with a common input structure and provides extensive graphical output capabilities. The program was acquired from PRC, installed on the Sun Sparcstation #2 in the secure NPS (Wargaming, Analysis, and Research Laboratory (WAR Lab), evaluated as the first Beta site for PRC, and used to determine the effect of RCS reduction on detection range. In addition, a user's manual was prepared, generic scenarios were

developed for use in AA 3251, "Aircraft Combat Survivability," and the program was compared with EADSIM. (2) EADSIM: This unclassified program was developed by Teledyne Brown Engineering for the US Army Space and Strategic Defense Command. It is a very powerful analysis tool that can model many aspects of air warfare. The program was acquired, installed on the NPS Computer Center Visualization Laboratory's (Vis Lab) Silicon Graphics Power Series 380/VGX. The Vis Lab was used because the program is unclassified; this allows freer access to the program by more students and faculty. Generic AAW and Strike Warfare scenarios were developed for use in AA 3251 and AA 3705, "Air Defense Lethality." A user's manual was prepared, and the program was used to study the effects of changes in weapon lethality on air defense lethality within a simulation.

THESES DIRECTED: Armantrout, J.T., LT, USN, "Adaptation of ACES/PHOENIX for Aircraft Combat Survivability Assessment at the Naval Postgraduate School," Master's Thesis, June 1993.

Bourassa, N.R., LCDR, USN, "Modeling and Simulation of Fleet Air Defense Systems Using EADSIM," Master's Thesis, June 1993.

DOD KEY TECHNOLOGY AREA: Design Automation.

KEYWORDS: Aircraft, Air Defense, Survivability, Lethality, Modeling, Simulation.

F-14A/B UPGRADE PROGRAM SUSCEPTIBILITY ASSESSMENT

R.E. Ball, Professor

Department of Aeronautics and Astronautics

**Sponsor and Funding: Naval Air Warfare Center, Weapons Division,
Point Mugu, CA**

OBJECTIVE: The objective of this project is to develop a methodology that can be used to assess the enhanced survivability of an aircraft due to the six susceptibility reduction concepts (threat warning, noise jamming and deceiving, signature reduction, expendables, threat suppression, and tactics). This methodology will be used to assess the enhanced survivability of the F-14A/B due to the 1991 Upgrade Program.

SUMMARY: The F-14 A and B versions of the Tomcat are undergoing an Electronic Combat system upgrade in order to meet current and future threats and to improve its combat survivability. The Upgrade Program consists of an improved radar warning system and displays - the ALR-67D(V)2), an improved active electronic countermeasures system - the ALQ-126B, and a significant increase in expendable chaff - the BOL system.

No standard methodology exists within the survivability community to assess the effectiveness of all of the susceptibility reduction concepts used in the Upgrade Program. Consequently, this project consists of the development of a methodology

that can be used to perform a susceptibility assessment on any platform in preparation for the subsequent F-14A/B Upgrade Program assessment. The methodology employs (1) a modified Systematic Systems Approach to weigh and compare performance measures, (2) probability trees to perform the campaign analysis, and (3) nonparametric statistical techniques to organize and analyze susceptibility data. A simple example was developed to illustrate the methodology. Additionally, the aerodynamic models for the F-14A and F-14B were constructed and added to the database of the BLUEMAX II Flight Path Generator section of the ACES/PHOENIX survivability analysis software package. This data is needed for the subsequent survivability studies of the F-14.

THESIS DIRECTED: Watson, T.C., III, LCDR, USN, "F-14A/B Upgrade Program Susceptibility Assessment Methodology," Master's Thesis, December 1993.

DOD KEY TECHNOLOGY AREA: Other.

KEYWORDS: Aircraft, F-14, Survivability, Susceptibility.

**EVALUATION OF UTSI PROGRAM ON OPTICAL MEASUREMENTS OF TURBINE
EXHAUST PARTICULATES**

O. Biblarz, Professor

D.W. Netzer, Professor

Department of Aeronautics and Astronautics

Sponsor and Funding: Naval Air Warfare Center - Aircraft Division

OBJECTIVE: To provide an independent evaluation of the theoretical and experimental approaches which have been used by the University of Tennessee Space Institute's Center for Laser Applications for the measurement of soot size and optical properties in gas turbine engine exhausts.

SUMMARY: An evaluation was made based upon the published literature of UTSI-CLA. Specific conclusions and recommendations were included in the final report submitted to the NAWCAD. A new, simpler technique for measuring the concentration of soot in gas turbine exhaust plumes has been proposed.

OTHER: Biblarz, O. and Netzer, D.W.,

"Evaluation of UTSI-CLA Program on Optical Measurements of Turbine Engine Exhaust Particulates," NPS Technical Report NPS-AA-94-001CR.

Netzer, D.W. and Biblarz, O., "Particle Sizing in Propulsion Systems," Tutorial Notes provided to NAWCAD.

Biblarz, O. and Netzer, D.W., "Determination of Soot Concentration from Transmission Measurements," patent application prepared December 1993 (NC 76,165).

DOD KEY TECHNOLOGY AREA: Other.

KEYWORDS: Soot, Pollution.

**COMPRESSIBILITY EFFECTS ON AND CONTROL OF DYNAMIC STALL OF
OSCILLATING AIRFOILS**

M.S. Chandrasekhara, Research Associate Professor

M.F. Platzer, Professor

Department of Aeronautics and Astronautics

Sponsor and Funding: U.S. Army Research Office

OBJECTIVE: To study the effects of compressibility effects on dynamic stall of oscillating airfoils and control the process of dynamic stall. The research has application in helicopter 'retreating blade stall'. The knowledge is useful in extending the flight envelope of future helicopter systems. On-going program since March 1990.

SUMMARY: The flow over a helicopter retreating blade is simulated in a wind tunnel facility known as the compressible dynamic stall facility (CDSF). The experimental flow conditions are such that the helicopter flight envelope is simulated. The reporting period saw two major accomplishments. One is the identification of a method of 'tripping' the blade boundary layer such that the full scale flight Reynolds numbers effects are approached in the laboratory. Another is the development of a high speed camera system to obtain very high speed real-time point diffraction interferometry (PDI) flow images. The successful development of this challenging instrumentation system now enables documenting and studies of the rapid flow changes in a single oscillation cycle, which is critical to understanding the physics of the unsteady flow separation. Further, a fringe analysis software package has been developed to map the flow pressure field from the measured density field. With these, an unparalleled capability now exists that permits measurements of the flow changes when control efforts are implemented.

PUBLICATIONS: Chandrasekhara, M.S. and Ahmed, S., "Velocity and Vorticity Distributions Over an Oscillating Airfoil Under Compressibility Conditions," AIAA Journal, Vol. 31, No.6, pp. 995-996, June 1993.

Ahmed, S. and Chandrasekhara, M.S., "Reattachment Studies of an Oscillating Airfoil Dynamic Stall Flow Field," AIAA Journal, accepted for publication September 1993.

CONFERENCE PRESENTATIONS:

Chandrasekhara, M.S., "Oscillating Airfoil Compressible Dynamic Stall Flow Field," Invited Paper, International Symposium on Advances in Aerospace Sciences and Engineering, Bangalore, India, 12-14 December 1992.

Chandrasekhara, M.S. and Van Dyken, R.D., "LDV Measurements in Dynamically Separated Flows," The Fifth International Conference on Laser Anemometry - Advances and Applications, Koningshof, Veldhoven, The Netherlands, 23-27 August 1993.

Ekaterinaris, J.A., Platzer, M.F. and Chandrasekhara, M.S., "Low Reynolds Number Airfoil Predictions," 45th American Physical Society Fluid Dynamics Meeting, Tallahassee, FL, 22-24 November 1992.

DOD KEY TECHNOLOGY AREA: Other.

KEYWORDS: Unsteady Separated Flow, Flow Control, Interferometry, High Speed Imaging.

CONTROL OF DYNAMIC STALL OF AND COMPRESSIBILITY
EFFECTS ON TRANSIENTLY PITCHING AIRFOILS
USING ADAPTIVE GEOMETRIES

M.S. Chandrasekhara, Research Associate Professor
M.F. Platzer, Professor
Department of Aeronautics and Astronautics
Sponsor and Funding: AFOSR

OBJECTIVE: To develop a deployable means of controlling the unsteady separated flows over a maneuvering wing by using wing geometries that adapt to the instantaneous flow over it. The research has application in enhancing the maneuverability of fighter aircraft. Initiated in October 1992 as a follow-on effort to the basic studies carried out in the previous years.

SUMMARY: The flow over a transiently pitching aircraft wing (or airfoil) has been studied in the past to obtain a proper understanding of the compressibility effects that cause loss of lift and premature stall of pitching wings. It was identified that a reasonable means of controlling the flow could be developed if the flow induced adverse pressure gradients over the wing could be favorably modified. Such a means would require instantaneous change of the wing shape. In other words, the wing should "adapt" to the local flow conditions on a continuous basis. However, this is a very challenging task. In an effort towards reaching this goal, a new electro-expulsive de-icing device on the wing leading edge was tested. Since the deformation produced by this was highly irregular it was not acceptable. Currently, a new wing whose leading edge is fabricated from a composite material is being constructed. Additionally, the drive

system that produces the necessary forces to deform the surface is being designed. Testing is expected to commence shortly.

PUBLICATIONS: Chandrasekhara, M.S., Ahmed, S., and Carr, L.W., "Schlieren Studies of Compressibility Effects on Dynamic Stall of Airfoils in Transient Pitching Motion," Journal of Aircraft, Vol. 30, pp. 213-220, 1993.

Chandrasekhara, M.S., Carr, L.W., and Wilder, M.C., "Interferometric Investigations of Compressible Dynamic Stall Over a Transiently Pitching Airfoil," AIAA Journal, accepted for publication, July 1993.

CONFERENCE PUBLICATIONS: Chandrasekhara, M.S., Wilder, M.C., and Carr, L.W., "Transition Effects on Compressible Dynamic Stall of Transiently Pitching Airfoils," AIAA 24th Fluid Dynamics Conference, 6-9 July 1993.

Cho, Y.C., Carr, L.W., and Chandrasekhara, M.S., "Corrections to Fringe Distortion Due to Flow Density Gradients in Optical Interferometry," AIAA 31st Aerospace Sciences Meeting, 11-14 January 1993.

DOD KEY TECHNOLOGY AREA: Other.

KEYWORDS: Unsteady Flow Control, Smart Materials, Interferometry.

**SMALL SCALE WIND TUNNEL INVESTIGATION OF
F/A-18 AIRCRAFT AT HIGH ANGLES OF ATTACK**

S.K. Hebbar, Adjunct Professor

M.F. Platzer, Professor

Department of Aeronautics and Astronautics

Sponsor and Funding: NASA Ames Research Center

(Non-monetary support)

OBJECTIVE: This was the continuation of the second project of a series of cooperative studies of F/A-18 between the Aero/Astro Department of the NPS and the Fixed-wing Aerodynamics Branch of NASA Ames Research Center aimed at studying the interaction between the F/A-18's LEX vortex and the vertical tail surfaces, with and without the LEX fences.

SUMMARY: The vortex wake data collected downstream of a 3% scale model of the YF-17 lightweight fighter prototype mounted at high angles of attack in the NPS low speed wind tunnel was examined to make appropriate recommendations to NASA in support of a full scale testing of F/A-18 in the NASA-Ames 80-ft x 120-ft wind tunnel. During the period under review (last year of the multi-year program), the earlier data from hot wire surveys and power spectra measurements (already reported in a M.S. Thesis) was further analyzed and a comprehensive report prepared and submitted to NASA Project Director, NFAC.F-18 High Alpha Test.

PUBLICATION: Hebbar, S.K., Platzer,

M.F., and Frink, W.D., Jr., "Vortex Wake Investigation of a Twin-Tail Fighter Aircraft Model at High Angles of Attack with and without LEX Fences," AIAA Paper 93-0868, January 1993.

CONFERENCE PRESENTATION: Hebbar, S.K., Platzer, M.F., and Frink, W.D., Jr., "Vortex Wake Investigation of a Twin-Tail Fighter Aircraft Model at High Angles of Attack with and without LEX Fences," AIAA 31st Aerospace Sciences Meeting, Reno, Nevada, January 1993.

OTHER: The principal investigator (SKH) received NASA Group Achievement Award for contribution to F/A-18 high angle of attack test program. The results of this investigations are being summarized in the form of a Technical/Engineering Note for publication in a Journal.

DOD KEY TECHNOLOGY AREA: Other.

KEY WORDS: High Angle of Attack, F/A-18, Vortex Wake, LEX Fence, Hot-wire Surveys, Turbulence Power Spectra.

TURBINE TIP-LEAKAGE FLOWS

G.V. Hobson, Associate Professor

Department of Aeronautics and Astronautics

Sponsor and Funding: NAWC Aircraft Division, Trenton

OBJECTIVE: This project entails the systematic measurements of highly swirling turbine flows with a newly commissioned three-component fibre-optics laser Doppler velocimeter (LDV), in test articles of small size at realistic Mach numbers. The objective of the project is to develop techniques necessary to obtain non-intrusive LDV data in the tip-leakage region of operating turbines, as these flows account for significant losses. The problems associated with optical access windows, and seeding material are to be addressed in an annular turbine cascade (ATC), and then LDV measurements will be performed in the turbine of the High Pressure Fuel TurboPump (HPFTP) for the Space Shuttle Main Engine (SSME).

SUMMARY: The design of the ATC was completed by Lt G. Thomas. Successful probe measurements were performed downstream of the annular turbine cascade. These entailed three-hole cobra probe measurements of total pressure, local Mach number and flow angle over one blade pitch and at seven different radial positions. Before the tunnel was complete, Lt. G. Thomas successfully ran RVC3D (Rotor Viscous Code 3-D by Rod Chima of NASA Lewis Research Center) on the ATC geometry. Initial predictions

showed that a wall jet was to form close to the hub endwall downstream of the blades. These results were unexplained and thus considered to be suspect, as they did not show the more familiar wake flow profiles, which were predicted for the rest of the annulus. However, the initial probe measurements showed that these predictions were correct as the wall jet was a result of the secondary flow energizing the hub wall boundary layer. LDV measurements are planned in the coming year. The knowledge gained from this rig will be used to design and manufacture an optical access window for the turbine test rig. The current test article is the HPFTP for the SSME, and the configuration to be initially tested is the Alternate TurboPump Design (ATD) which Pratt and Whitney manufactured.

THESIS DIRECTED: Thomas, G.D., LT, USN, "Measurement and Prediction of the Flow Through an Annular Turbine Cascade," Master of Science in Aeronautical Engineering, September 1993.

DOD KEY TECHNOLOGY AREA: Propulsion and Energy Conversion.

KEYWORDS: Turbine, Laser Doppler Velocimeter, Tip Leakage.

TRANSONIC TURBINE RIG

**G.V. Hobson, Associate Professor
Department of Aeronautics and Astronautics
Sponsor and Funding: Naval Postgraduate School**

OBJECTIVE: This proposed work will provide three-component laser Doppler velocimetry (LDV) measurements of transonic flows, as well as total and static pressure distributions, in an annular turbine cascade (ATC) of highly loaded turbine blades. Non-intrusive measurements will be performed with the three-component fibre-optics LDV system. Mean flow and turbulence quantities will be mapped out in detail downstream of the cascade. Three-dimensional viscous flow simulations of the turbine flowfield will also be performed to assess the ability of codes to predict such flows.

SUMMARY: This research project is aimed at obtaining detailed three-dimensional viscous flow measurements in an annular turbine cascade. Three-component LDV measurements have been performed in the corner vortex flow of the Low Speed Cascade. Lt. Perretta performed transonic LDV measurements with a one-component LDV system in the Gas Dynamic Laboratory's supersonic blow down wind tunnel. These measurements en-

tailed flowfield surveys across a normal shock in a Mach 1.4 flow, and boundary layer surveys ahead of the shock. Bimodal histograms of the unsteady shock process were measured, and the feasibility of performing backscatter measurements was achieved. Lt. Utschig performed preliminary two component CDV measurements in between the blade rows of a low speed multi-stage compressor. Both the above projects will assist in the measurement of transonic turbine flows.

THESES DIRECTED: Perretta, D.A., LT, USN, "Laser Doppler Velocimetry Measurements Across a Normal Shock in Transonic Flow," Master of Science in Aeronautical Engineering, March 1993.

Utschig, J., LT, USN, "Laser Doppler Velocimetry in a Low Speed Multistage Compressor," Master of Science in Engineering Science, September 1993.

DOD KEY TECHNOLOGY AREA: Propulsion and Energy Conversion.

KEYWORDS: Fluid Dynamics.

STRAKE AND WING BLOWING FOR VORTEX FLOW CONTROL
ON A CROPPED DOUBLE-DELTA CONFIGURATION

R.M. Howard, Associate Professor
Department of Aeronautics and Astronautics
Sponsor and Funding: Naval Postgraduate School

OBJECTIVE: The goal of this project was to perform a wind-tunnel investigation of the application of wind-strake blowing for vortex flow control over highly-swept surfaces. Measured were the parameters of lift and drag. This project is part of an ongoing study of enhanced high-angle-of-attack aerodynamics.

SUMMARY: The maintenance of air superiority in the future will depend on maneuvering into the post-stall flight regime, requiring enhanced lift at high angles of attack. Enhanced lift often depends on the formation of strong vortices generated from aircraft strake and wing leading edges, which lift can be compromised by vortex breakdown. Recent studies have used flow-visualization techniques to observe flowfield changes due to pneumatic blowing over wings and strakes, but direct measurements of lift and drag are lacking. Various blowing port locations, port sweep angles, port inclination angles and blowing coefficients were treated. A maximum lift enhancement of 9 percent was found for blowing port 1 located near the strake apex, at a tube sweep angle of 60 degrees and inclination angle of 0 degrees, at an aircraft angle of attack of 20 degrees. Up to the maximum blowing coefficient of

0.022, lift increased linearly with blowing coefficient. If the linear trends continue at higher blowing coefficients (achievable by other investigators), lift increases of from 12 to 25 percent may be possible.

CONFERENCE PRESENTATION: Howard, R.M. and O'Leary, J.F., "A Flowfield Study of a Close-Coupled Canard Configuration," AIAA Paper 93-3499, AIAA Applied Aerodynamics Conference, Monterey, CA, 9-11 August 1993.

THESES DIRECTED: Zraggen, C.J., LT, USN, "Lift Enhancement of A Wing/Strake Using Pneumatic Blowing," Master's Thesis, March 1993.

McBane, D.G., LT, USN, "Close-Coupled Oscillating Canard Effects on Post-Stall Lift Enhancement," Master's Thesis, June 1993.

OTHER: A journal article on related prior work is awaiting publication in the Journal of Aircraft, and a paper has been accepted for presentation at the AIAA Atmospheric Flight Mechanics Conference.

DOD KEY TECHNOLOGY AREA: Other.

KEYWORDS: High-Angle-of-Attack, Vortex, Strake.

AIR-MOBILE GROUND SECURITY SYSTEM PLATFORM ASSESSMENT

R.M. Howard, Associate Professor

I.I. Kaminer, Assistant Professor

Department of Aeronautics and Astronautics

**Sponsor and Funding: Naval Command, Control and
Ocean Surveillance Center**

OBJECTIVE: The goal of this project as to assist the sponsor in the evaluation of advanced-technology unmanned air vehicles under contract. In particular, NPS expertise was needed in the areas of vehicle performance, stability and control, guidance and navigation, and communications. This is an ongoing project.

SUMMARY: The Naval Command, Control and Ocean Surveillance Center, RDT&E Division (NRaD), solicited advanced development technology proposals to support the Air-Mobile Ground Security System Program. The mission of the program is to enhance the effectiveness of rear-area physical security and force protection through extended range surveillance, area intrusion detection, assessment and identification. The air-mobile platform has demanding requirements, such as vertical takeoff and landing (VTOL), ducted-fan propulsion, and autonomous operation.

First, evaluations were made of the various proposals submitted of an air vehicle designed to perform the mission. From the inputs of the Principal Investigators and members on the NRaD staff, awards were made

to three contractors. On-site demonstrations followed, with field tests of the various air vehicles. Input from the Principal Investigators was received in the way of oral and written reports. An important issue of concern was the sensor suite necessary to carry out the required mission. A study was performed of optimal blending of INS (Inertial Navigation System) and GPS (Global Positioning System) information. The project is expected to continue as the program moves into Phase II.

THESIS DIRECTED: Marquis, J.P. III, LT, USN, "Integration of Differential GPS and Inertial Navigation Using a Complementary Kalman Filter," Master's Thesis, September 1993.

OTHER: A thesis project is underway determining the performance trade-offs between various ducted-fan, single- and multi-rotor VTOL air vehicles.

DOD KEY TECHNOLOGY AREA: Sensors.

KEYWORDS: Unmanned Air Vehicle, UAV, Sensors, VTOL, Ducted Fan.

**DEVELOPMENT OF A TRAINING AID FOR
AIRCRAFT FLYING IN CLOSE PROXIMITY**

R.M. Howard, Associate Professor

Department of Aeronautics and Astronautics

Sponsor and Funding: Naval Air Systems Command

OBJECTIVE: The goal of this project was to conduct a computer analysis of the aerodynamic interference between dissimilar aircraft flying in close formation, and to produce a training video from the computer graphics to educate fleet aviators in the hazards of formation flying.

SUMMARY: During an in-flight emergency such as an unsafe landing-gear indication, a second aircraft may be sent aloft for a visual inspection. The inherent danger involved with aircraft flying in close proximity, especially aircraft very dissimilar in size and wing loading, may not be sufficiently stressed during flight safety training. A numerical study of the aerodynamic interference between an F-14 and a T-34 aircraft flying in close formation was conducted. Two cases were treated: one with the T-34 closing vertically on the F-14 from beneath, and the second with the T-34 closing horizontally on the F-14 in a step-down position. Graphical output consisted of plotted streamlines, pitching moments, reduced lift, elevator angle to trim, and color plots of surface pressures on the T-34 wing and tail. It was found that a strong nose-up pitching moment resulted from the downwash

from the larger lead aircraft. This pitching moment was coupled with a reduction in lift due to the trailing aircraft's location on the pressure side of the lead aircraft. As a result, the pilot would have the sensation of a nose-up pitching tendency while being "pushed away" - conflicting cues for the pilot as the aircraft close to within a wingspan distance. An understanding of the aero-dynamic interference and the expected lift and trim changes by trained fleet aviators should help to avoid the possibility of a collision.

THESIS DIRECTED: Porter, D.B., LCDR, USN, "A Numerical Study of Airplanes Flying in Proximity," Master's Thesis, September 1993.

OTHER: An important product of this work was a training video produced for the sponsor, copies of which will be distributed along with a short report to the various fleet aircraft training commands to support flight safety training. A paper has been accepted for presentation at the AIAA Atmospheric Flight Mechanics Conference.

DOD KEY TECHNOLOGY AREA: Other.

KEYWORDS: Formation Flying, Panel Methods, Flight Training.

**DEVELOPMENT OF A VTOL UNMANNED AIR VEHICLE
FOR TRANSITIONAL FLIGHT**

R.M. Howard, Associate Professor

I.I. Kamner, Assistant Professor

Department of Aeronautics and Astronautics

Sponsor and Funding: Naval Air Systems Command

OBJECTIVE: The goal of this project was to develop a vertical-takeoff-and-landing Unmanned Air Vehicle (UAV) as a technology demonstrator for the VTOL mission. The effort included airframe design and construction, modelling, simulation, sensor and datalink integration, and testing. This is an ongoing effort.

SUMMARY: The current inventory of UAVs lacks a suitable platform able to meet the increased need for real-time intelligence in fleet operations from small surface combatants. Limited shipboard assets and launch-and-recovery capabilities call for systems small and more readily deployable than current systems. A candidate for the VTOL mission must not only takeoff and land vertically, but also transition to horizontal flight for a high dash speed and efficient loiter capability. Assets from two cancelled programs were combined to provide a novel airframe concept for the vehicle. The Archytas air vehicle is a tailsitter design, with a ducted-fan propulsion system for efficiency and safety, and with wings and a canard tail surface for horizontal flight. The wing spars joining the wings to the airframe were designed, tested, and fabricated. Prior to making the attachment, thrust and torque tests were completed with the ducted-fan unit. A spread-spectrum datalink system was designed and tested on the fixed-wing testbed, for later use on the Archytas. A non-linear six-degree-of-freedom (6-DOF) motion model, along with sensor and actuator models, were developed and tested

with an aerodynamic model of the hovering air vehicle. A Kalman filter was developed to integrate Differential GPS (DGPS) and an Inertial Measurement Unit (IMU) for autoland applications. A robust Multi-Input Multi-Output (MIMO) controller was designed for the Archytas and tested in hardware-in-the-loop simulation. Continued work is leading to hover tests and the pitch-over maneuver.

THESES DIRECTED: Stoney, R.B., LCDR, USN, "Design, Fabrication and Test of a Vertical Attitude Takeoff and Landing Unmanned Air Vehicle," Engineer's Thesis, June 1993.

Kaltenberger, B.R., LT, USN, "RPV/UAV Survey towards a Lethal UAV," Master's Thesis, September 1993.

Kuechenmeister, D.R., CAPT, USMC, "A Non-Linear Simulation for an Autonomous Unmanned Air Vehicle," Master's Thesis, September 1993.

Marquis, C.W. III, LT, USN, "Integration of Differential GPS and Inertial Navigation Using a Complementary Kalman Filter," Master's Thesis, September 1993.

Fordham, J.P., LT, USN, "Design and Monte Carlo Analysis of an Unmanned Aerial Vehicle," Master's Thesis, December 1993.

DOD KEY TECHNOLOGY AREA: Sensors.

KEYWORDS: VTOL, Unmanned Air Vehicle, UAV, Autoland, Simulation, Sensors.

**APPLICATION OF H_INFINITY AND MIXED
H_0/H_INFINITY SYNTHESIS TO THE DESIGN OF
ROBUST TRACKING CONTROLLERS AND RELATED THEORY**

**I.I. Kaminer, Assistant Professor
Department of Aeronautics and Astronautics
Sponsor and Funding: Naval Postgraduate School**

OBJECTIVE: The ongoing goal of this project is to investigate the application of H_∞ and mixed H_2/H_∞ synthesis techniques to the design of robust tracking controllers. Furthermore, should there be a lack of theoretical tools needed to accomplish this task, such tools will be developed.

SUMMARY: In the work covered by this proposal we addressed certain issues which are important to the design of control systems for combat aircraft. In particular, we applied recently developed robust control design methodologies to synthesize an automatic carrier landing controller for F-14. In general such controllers are designed for linear models of the plant around a number of nominal operating conditions. It turns out that for a certain class of nonlinear plants such designs result in gain-scheduled controllers. The issue of properly implementing such controllers has received little attention in the literature. Therefore, we are in the process of developing a methodology to properly design and implement gain-scheduled controllers on the nonlinear plants with applications to motion control of rigid bodies.

PUBLICATIONS: Kaminer, I., Khargonekar, P.P., and Rotea, M.A., "Mixed H_2/H_∞ Control for Discrete Time Systems Via Convex Optimization," Automatica, Vol. 29, No. 1, pp. 57-70, 1993.

Rotea, M.A. and Kaminer, I., "Generalized H_2/H_∞ Control

of Discrete-Time Systems," in Proceedings of the 1993 International Forum on Automatic Control," Melbourne, Australia, Vol. 5, pp. 239-243, July 1993.

Kaminer, I., Pascoal, A.M., Khargonekar, P.P., and Thompson, C., "A Velocity Algorithm for the Implementation of Nonlinear Gain-Scheduled Controllers," in Proceedings of the European Control Conference, Groningen, Netherlands, pp. 787-791, June 1993.

Sivashankar, N., Kaminer, I., and Khargonekar, P.P., "Optimal Controller Synthesis with D-stability," in Proceedings of the Conference on Decision and Control, San Antonio, TX, pp. 110-115, 1993.

Kaminer, I., Pascoal, A.M., Khargonekar, P.P., and Silvestre, C., "A Velocity Algorithm for the Implementation of Gain-Scheduled Controllers with Applications to Rigid Body Motion Control," in Proceedings of the Conference on Decision and Control, pp. 1043-1048, 1993.

CONFERENCE PRESENTATIONS: Kaminer, I., Pascoal, A.M., Khargonekar, P.P., and Thompson, C., "A Velocity Algorithm for the Implementation of Nonlinear Gain-Scheduled Controllers," European Control Conference, Groningen, Netherlands, June 1993.

Sivashankar, N., Kaminer, I., and Khargonekar, P.P., "Optimal Controller Synthesis with

D-stability," Conference on Decision and Control, San Antonio, TX, 1993.

Kaminer, I., Pascoal, A.M., Khargonekar, P.P., and Silvestre, C., "A Velocity Algorithm for the Implementation of Gain-Scheduled Controllers with Applications to Rigid Body Motion Control," Conference on Decision and Control, 1993.

DOD KEY TECHNOLOGY AREA: Design Automation, Other.

KEYWORDS: Flight Control Systems, Gain-scheduled Controllers, Nonlinear Control, Robust Control.

ADVANCED AVIONICS TECHNOLOGY

I.I. Kaminer, Assistant Professor

Department of Aeronautics and Astronautics

Sponsor and Funding: Naval Air Systems Command - AIR546TD

OBJECTIVE: To perform research and development in advanced avionics technology topics.

SUMMARY: In the work covered by this project we addressed certain issues which are important for the design of avionics systems for air vehicles. In particular, we investigated the applicability of various sensor and actuator failure detection and isolation techniques (FDI) to the failure detection and isolation problem in a close range aircraft. Next, we developed a differential GPS/INS navigation system to be used by the aircraft waypoint guidance system. Finally, in order to facilitate proper development and testing of the above systems we developed a high fidelity six degree of freedom nonlinear model of the close range aircraft and built a real-time hardware-in-the-loop simulation station.

THESES DIRECTED: Marquis, Carl W., "Integration of Differential GPS and Inertial Navigation Using Complementary Kalman Filter," Master's Thesis, September 1993.

Kuechenmeister, David R., "Nonlinear Simulation for an Autonomous Unmanned Air Vehicle," Master's Thesis, September 1993.

Levesque, Mario, J.L., "Fault Detection and Isolation for Bluebird Testbed Aircraft," Master's Thesis, December 1993.

OTHER: The investigator supported a visit by Dr. N. Sivashankar. The work done during this visit is summarized in the following technical report: "Design, implementation and hardware-in-the-loop testing of MIMO controller using H_{∞} synthesis for a VTOL aircraft."

DOD KEY TECHNOLOGY AREA: Design Automation.

KEYWORDS: Navigation, Filtering, Simulation, Sensor Failure Detection and Isolation.

AIRCRAFT STRUCTURAL LIFE SURVEILLANCE PROGRAM

G.H. Lindsey, Professor

Department of Aeronautics and Astronautics

Sponsor and Funding: Naval Air Systems Command,
Structures Branch (Code 5302)

OBJECTIVE: This work encompasses collecting and documenting details of the Naval Air Systems Command's Aircraft Structural Life Surveillance (ASLS) Program and transforming that information into educational materials for use in AA 3202, Aircraft Structural Fatigue and Fracture.

SUMMARY: One of the customary payback tours for officers completing the 610 curriculum is the Naval Air Systems Command. Many who receive these assignments will work directly on, or interact closely with, the ASLS program. It is crucial that all who so interface have a good understanding of how the service life of aircraft are established, tracked, assessed, and extended, and the theoretical basis for each aspect. Two years ago, NPS introduced course devoted to aircraft structural fatigue and fracture into the Aeronautical Engineering Curriculum. This reimbursable project was undertaken to better prepare officers for assignments at NAVAIR by incorporating into classical aircraft fatigue theory and practice, the specific programs developed by the Navy to manage its large and varied fleet of aircraft and helicopters. The work was accomplished by on-site visits to the Structures Branch of the Air Vehicle Division to collect information from personal interviews and written reports. This information was sifted and organized into written and visual classroom materials for use at NPS. The syllabus of the course was completely rewritten to incorporate the new material while balancing theory and

practice. The new course was taught Fall Quarter, 1993. Corrections and revisions are now being made to refine the syllabus in preparation for the next presentation of the course beginning March, 1994.

OTHER: Nine "Readings" Papers were prepared by abstracting materials from a variety of sources. These papers were printed and distributed to the class and comprised a portion of the study materials:

Reading I: Naval Aircraft Structural Integrity Program (NASIP), Abstracted from NADC Report 87089-60, 28 October 1993.

Reading II: Flight Loads Diagrams, Abstracted from MIL-SPEC 8860B, 29 September 1993.

Reading III: External Flight Loads, Abstracted from loads manual of Airframe Contractor.

Reading IV: Generating a Fatigue Spectrum for F/A-18 E,F, Abstracted from McDonnell Report 92B0312, 6 October 1993.

Reading V: Navy Aircraft Design & Certification Philosophy, Paper presented at the International Conference on Aircraft Damage Assessment & Repair, 20 October 1993.

Reading VI: Theories of Static Yielding, a review paper summarizing current knowledge, 25 October 1993.

Reading VII: Static Strength Theories, a review paper summarizing current knowledge, 1 November 1993.

Reading VIII: Full Scale Ground Tests, Abstracted from MIL-SPEC-A-8867C, 29 November 1993.

Reading IX: Aircraft Structural Life Surveillance Program, Abstracted from NADC Report 87089-60, 6 December 1993.

DOD KEY TECHNOLOGY AREA: Other.

KEYWORDS: Aircraft Fatigue
Structural, Integrity Fatigue
Tracking.

COMBUSTION BEHAVIOR IN AIRBREATHING MISSILES

D.W. Netzer, Professor

Department of Aeronautics and Astronautics

Sponsor and Funding: Naval Air Warfare Center,
Weapons Division

OBJECTIVES: To (1) upgrade the MICROPEP aerothermochemical code to increase utility for airbreathing applications, (2) correlate bypass air experimental results with CFD code predictions to explain the effects of bypass dump momentum on combustion efficiency, (3) evaluate ultrasonic atomizers for improved atomization and combustion efficiency of gelled slurry fuels, (4) develop an experimental apparatus that can be used for evaluation of ignition and combustion characteristics of metal and liquid fuels and (5) evaluate the effect of fuel injection location and side-dump configurations on combustor fuel distribution.

SUMMARY: The MICROPEP code was modified to allow calculation of the effects of non-ideal expansion and mixed shifting equilibrium-frozen composition flow on performance. Vitiated air was incorporated as well as the calculation of combustor Mach number and stagnation pressure for airbreathing engines. A 3-D model of the flow in the aft-burner of a B₄C fueled solid fuel ramjet motor was developed and solved numerically. Low bypass dump momentum was shown to increase combustion efficiency (observed experimentally) through the reduction of particle collision/extinguishment with the motor walls. Ultrasonic and air-blast atomizers were evaluated for droplet distributions and combustion efficiency in a center-dump ramjet combustor. Ultrasonic atomization was found to be superior for the gelled slurry fuel. An apparatus was designed and fabricated for determining ignition and combustion

characteristics of metallic fuel particles and liquid fuel droplets. It consisted of a small windowed combustion bomb, a CO₂ laser for ignition, a thermal imaging camera for recording the ignition process and a phase-Doppler particle analyzer for measuring the particle size. A water tunnel was used with laser sheet illumination to determine that combustor dome lengths between 0.31D and 1.4D are required for obtaining good fuel distribution in the flame stabilization region. Optimum inlet dump fuel injection locations were also identified.

PUBLICATIONS: Angus, W.J., Witt, M.A., Laredo, D., and Netzer, D.W., "Solid Fuel Supersonic Combustion," La Recherche Aerospatiale, 1993-6, pp. 1-8, November-December 1993.

Angus, W.J., Witt, M.A., Laredo, D., and Netzer, D.W., "Solid Fuel Supersonic Combustion," in Proceedings of the 29th JANNAF Combustion Subcommittee Meeting, CPIA Pub. 593, Vol. II, pp. 47-57, October 1992.

THESES DIRECTED: Mcatee, A.M., "Adaptations to "MICROPEP" and "ROCKET" to Allow Performance Evaluation of Multiple Grain and/pr Airbreathing Motors," Master's Thesis, June 1993.

Gulakowski, S., "An Apparatus for Measurement of Ignition and Burning Characteristics of Metallic Particles," Master's Thesis, September 1993.

Salzer, R.F., "Flow Visualization and

Experimental Optimization of Three Inlet-Side-Dump Liquid-Fuel Ramjet combustors," Master's Thesis, September 1993.

DOD KEY TECHNOLOGY AREA: Propulsion and Energy Conversion.

KEYWORDS: Ramjet Combustion, Side Dump Combustor, Fuel-Injection.

MEASUREMENTS OF PARTICULATE AND PLUME CHARACTERISTICS IN SOLID AND LIQUID PROPELLANT ROCKET MOTORS

D.W. Netzer, Professor

Department of Aeronautics and Astronautics

Sponsor and Funding: Air Force Phillips Laboratory

OBJECTIVES: To (1) use a quenched and non-quenched subscale motor with multiple diagnostic techniques to measure across-motor and across-nozzle particle size distribution changes for Al_2O_3 , (2) use secondary gaseous injection to determine if combustor gas composition changes can effect the optical properties of exhaust Al_2O_3 , (3) validate the ensemble particle sizer for use in the motor and plume environments by using control propellants, (4) determine the universality of plume edge particle size and optical properties and (5) demonstrate the use of a multiple-wavelength extinction apparatus for measurement of soot size and optical properties in liquid motor plumes.

SUMMARY: Good agreement was found between the particle sizes measured in the motor and plume using a Malvern (ensemble) particle sizer, an absolute intensity single particle analyzer and scanning electron microscope examination of particles collected on an impact probe and on the motor walls. A significant reduction in particle mean size with a reduction in the mass of particles less than two microns in diameter occurred from the propellant surface

to the nozzle entrance. Particle breakup dominated in the converging nozzle section, but significant collision coalescence occurred in the nozzle divergence. The mean size and optical properties of Al_2O_3 in the plume edge were found to be independent of propellant composition, motor operating conditions and nozzle geometry. Use of the phase-Doppler particle analyzer and the control propellants for Malvern validation were not accomplished until the first quarter of FY94 due to delays in receipt of the instrument and propellants. Changes in nozzle expansion ratio were found to affect the strengths and locations of the Mach disks and the mixing rates with the atmosphere (afterburning), but not the plume particle size distribution. Comparisons of the experimental data with predictions from the SPF-IIIR/SIRRM-II codes were made. Secondary gaseous injection into the combustion chamber at 5% by weight was found to produce insignificant changes in alumina emissivity and plume IR signature. A multiple-wavelength extinction apparatus was fabricated for measuring soot size and optical properties in plumes. Initial validations were conducted

PUBLICATIONS: Laredo, D. and Netzer, D.W., "The Dominant Effect of Alumina on Nearfield Plume Radiation," Journal of Quantitative Spectroscopy and Radiative Transfer, Vol. 50, No. 5, pp. 511-530, 1993.

Kim, H.-O., Laredo, D., and Netzer, D.W., "Measurement of Submicrometer Al_2O_3 Particles in Plumes," Applied Optics, Vol. 32, No. 33, pp. 6834-6840, November 1993.

Laredo, D., McCrorie, J.D., II, Vaughn, J.K., Kim, H.-O., and Netzer, D.W., "Plume Particle Size Distribution and Optical Properties," in Proceedings of the 20th JANNAF Exhaust Plume Technology Subcommittee Meeting, Kirtland AFB, NM, Vol. I, pp. 407-427, February 1993.

THESES DIRECTED: McCrorie II, J.D., "Particle Behavior in Solid Propellant Rocket Motors and Plumes," Master's Thesis, December 1992.

Vaughn, J.K., "Measurement of Sub-Micron Al_2O_3 Particles in Rocket Plumes," Master's Thesis, December 1992.

Yi, C.M., "Effects of Nozzle Expansion Ratio on Aluminized Solid Propellant Rocket Motor Plume Signature," Engineer's Thesis, June 1993.

Taylor, K.B., "Dual-Beam Multiple-Wavelength Light Transmittance Measurement for Particle Sizing in Rocket Motor Plumes," Master's Thesis, June 1993.

Roddenberry, D.S., "Additive Gas Effects on Solid Propellant Rocket Motor Plume IR Signature," Master's Thesis, June 1993.

DOD KEY TECHNOLOGY AREA: Propulsion and Energy Conversion.

KEYWORDS: Rocket Plume Signature, Particulate Measurements.

DYNAMIC LIFT STUDIES FOR ENHANCED FIGHTER MANEUVERABILITY

M.F. Platzer, Professor

S.K. Hebbar, Research Associate Professor

J.A. Ekaterinaris, Research Associate Professor

Department of Aeronautics and Astronautics

Sponsor and Funding: Naval Air Warfare Center,

Aircraft Division, Johnsville, PA

OBJECTIVE: Identify promising methods for the generation and exploitation of dynamic lift in order to achieve enhanced fighter aircraft maneuverability. To this end, perform detailed experimental studies on double delta wings and complete aircraft configurations in dynamic motion and obtain computational solutions for steady and unsteady high angle of attack wing flows.

SUMMARY: Water tunnel studies were conducted to determine the following effects: a) pitch rate/sideslip effects on leading-edge extension vortices of an F/A-18 aircraft model, b) dynamic effects during side-slipping of a canard-configured fighter model, c) the effect of canard oscillations on the vortical flow development, d) the effect of fillets on the vortex development over double-delta wings. Also, computational solutions were obtained for the vortical flow field and the vortex breakdown phenomenon on high angle of attack wing flows.

PUBLICATIONS: Hebbar, S.K., Platzer, M.F., and Kwon, H.M., "Vortex Breakdown Studies of a Canard-Configured X-31A-Like Fighter Aircraft Model," Journal of Aircraft, Vol. 30, No.3, pp. 405-408, May-June 1993.

Ekaterinaris, J.A. and Schiff, L.B., "Numerical Prediction of Vortical Flow over Slender Delta Wings," Journal of Aircraft, Vol. 30, No. 6, pp. 935-942, 1993.

CONFERENCE PRESENTATIONS: Frink, W., Hebbar, S.K., and Platzer, M.F., "Vortex Wake Investigation of a Twin-tail Fighter Aircraft Model at High Angles of Attack with and without LEX Fences," AIAA paper 93-0868, 31st Aerospace Sciences Meeting, Reno, NV, 11-14 January 1993.

Hebbar, S.K., Platzer, M.F., and Li, F.H., "A Visualization Study of the Vortical Flow over a Double-Delta Wing in Dynamic Motion," AIAA paper 93-3425, 11th Applied Aerodynamics Conference, Monterey, CA, 9-11 August 1993.

Hebbar, S.K., Platzer, M.F., and Liu, D.M., "Effect of Canard Oscillations on the Vortical Flowfield of a X-31A-Like Fighter Model," AIAA paper 93-3427, 11th AIAA Applied Aerodynamics Conference, Monterey, CA, 9-11 August 1993.

DOD KEY TECHNOLOGY AREA: Other.

KEYWORDS: Aircraft Aerodynamics, Vertical Flows.

AIRCRAFT AND JET ENGINE UNSTEADY FLOW COMPUTATIONS

M.F. Platzer, Professor

J.A. Ekaterinaris, Research Associate Professor

Department of Aeronautics and Astronautics

Sponsor and Funding: Naval Air Systems Command

OBJECTIVE: Develop computational methods and obtain computational solutions for steady and unsteady flows over fighter aircraft configurations and helicopter blades at high angles of attack and through jet engine compressors and turbines.

SUMMARY: Potential flow, viscous-inviscid interaction and compressible Navier-Stokes computations were completed to study the dynamic stall characteristics of oscillating and rapidly pitching airfoils and the interaction effects between airfoils. Also, Navier-Stokes solutions were obtained for subsonic flow over canard-wing configurations at high angles of attack.

PUBLICATIONS: Cebeci, Platzer, M.F., Jang, H.M., and Chen, H.H., "A Viscous Inviscid Interaction Approach to the Calculation of Dynamic Stall Initiation on Airfoils," ASME Journal of Turbomachinery, Vol. 115, pp. 714-723, October 1993.

Platzer, M.F., Neace, K.S., and Pang, C.K., "Aerodynamic Analysis of Flapping Wing Propulsion," AIAA paper 93-0484, 31st Aerospace Sciences Meeting, Reno, NV, 11-14 January 1993.

Ekaterinaris, J.A. and Platzer, M.F.,

"Computational Investigation of Unsteady Heat Transfer on Oscillating Airfoils," in Proceedings of the 11th National Heat Transfer Congress, Milano, Italy, pp. 353-363, 24-26 June 1993.

Clarkson, J.D., Ekaterinaris, J.A., and Platzer, M.F., "Computational Investigation of Airfoil Stall Flutter," in Proceedings of the 6th International Symposium on Unsteady Aerodynamics, Aeroacoustics and Aeroelasticity of Turbomachines and Propellers, Springer Verlag, pp. 415-432, 1993.

THESES DIRECTED: Riester, P.J., "A Computational and Experimental Investigation of Incompressible Oscillatory Airfoil Flow and Flutter Problems," Master's Thesis, June 1993.

Johnston, T.A., "Computational Investigation of the Compressible Dynamic Stall Characteristics of the Sikorsky SSC-A09 Airfoil," Master's Thesis, September 1993

DOD KEY TECHNOLOGY AREA: Other.

KEYWORDS: Aircraft Aerodynamics, Computational Fluid Dynamics, Turbomachinery Aerodynamics.

FLOW OVER MISSILE CONFIGURATIONS AT HIGH INCIDENCE

M.F. Platzer, Professor

J.A. Ekaterinaris, Research Associate Professor

S.K. Hebbar, Research Associate Professor

Department of Aeronautics and Astronautics

Sponsor and Funding: Naval Air Warfare Center, Weapons Division

OBJECTIVE: Develop Navier-Stokes solutions for the vortical flow over complete missile configurations in steady or maneuvering high angle of attack flight.

SUMMARY: Navier-Stokes computations were completed for subsonic flow over a close-coupled canard-wing configuration for which extensive experimental data are available for comparison. Also, Navier-Stokes solutions were obtained for subsonic flow over a representative missile configuration at high angle of attack. In addition, a new viscous-inviscid interaction method was developed for two-dimensional unsteady compressible airfoil flows. Also, force and moment data were acquired on a NAWC-designed missile.

CONFERENCE PRESENTATIONS: Platzer, M.F., Ekaterinaris, J.A., and Chandrasekhara, M.S. "Computational and Experimental Investigations of Airfoil Leading-Edge Separation Bubbles," Endstage Transition Workshop, Syracuse University, 16-17 August 1993.

Tuncer, I.H., Ekaterinaris, J.A., and Platzer, M.F., "A Viscous-Inviscid Interaction Method for 2-D Unsteady Compressible Flows," AIAA paper 93-3019, 24th AIAA Fluid Dynamics Conference, Monterey, CA, 9-11 August 1993.

Smith, E.H., Hebbar, S.K., and Platzer, M.F., "Aerodynamic Characteristics of a Canard-Controlled Missile at High Angles of Attack," AIAA paper 93-0763, 31st Aerospace Sciences Meeting, Reno, NV, 11-14 January 1993.

Smith, E.H., Hebbar, S.K., Platzer, M.F., and Salazar, M., "Aerodynamic Characteristics of the MMPT ATD Vehicle at High Angles of Attack," AIAA paper 93-3493, 11th Applied Aerodynamics Conference, Monterey, CA, 9-11 August 1993.

DOD KEY TECHNOLOGY AREA: Other.

KEYWORDS: Missile Ae dynamics, Vertical Flows, Computational Fluid Dynamics.

AERODYNAMICS OF OSCILLATING DEVICES AS LIFT AUGMENTORS

M.F. Platzer, Professor

S.K. Hebbar, Research Associate Professor

Department of Aeronautics and Astronautics

Sponsor and Funding: Naval Air Systems Command

OBJECTIVE: Investigate the unsteady flow physics of multi-element airfoils for potential application to enhance the aerodynamic performance characteristics of aircraft.

SUMMARY: An aerodynamic analysis of flapping airfoils and airfoil combinations was completed which demonstrated the Katzmayr effect of producing a forward thrust due to flapping. Furthermore, it was shown that there exist conditions of favorable interference between two flapping airfoils which enhance this propulsive effect. Flow visualization studies were completed in two wind tunnels which demonstrated the propulsive vortex shedding from flapping airfoils.

CONFERENCE PRESENTATIONS: Platzer, M.F., Neace, K.S., and Pang, C.K.,

"Aerodynamic Analysis of Flapping Wing Propulsion," AIAA paper 93-0484, 31st Aerospace Sciences Meeting, Reno, NV, 11-14 January 1993.

Wood, E.R., Platzer, M.F., Abourahma, A., and Couch, M.A., "On the Unsteady Aerodynamics of Higher Harmonic Control," Paper No. C17, Nineteenth European Rotorcraft Forum, Cernobbio, Italy, September 1993.

THESIS DIRECTED: Riester, P.J., "A Computational and Experimental Investigation of Incompressible Oscillatory Airfoil and Flutter Problems," Master's Thesis, June 1993.

KEY TECHNOLOGY AREA: Other.

KEYWORDS: Aircraft Aerodynamics, Unsteady Aerodynamics.

ENDOATMOSPHERIC SPACE TRAJECTORY ANALYSIS AND OPTIMIZATION

I.M. Ross, Assistant Professor

Department of Aeronautics and Astronautics

Sponsor and Funding: Naval Postgraduate School (RIP Program)

OBJECTIVE: This project was (and continues to be) aimed at investigating three problems: (1) optimality of singular trajectories (2) development of a new synergetic orbital plane-change maneuver and (3) analysis of uncontrolled satellite re-entry and impact prediction models.

SUMMARY: First-order singular arcs for a low-Earth-orbiting spacecraft were derived and expressed in state variable feedback form. A forced Keplerian trajectory was shown to be non-optimal in the Mayer sense and hence orbit maintenance fuel-budgeting was questioned. This led to an energy-management guidance algorithm whose details are currently being worked out. In addition, the "aerobang maneuver" was further developed to the point of showing its superiority over the more traditional aerocruise maneuver. The fuel-optimality of the total synergetic maneuver is still under investigation. Finally, a thesis directed on a comprehensive literature review of uncontrolled satellite re-entry and impact prediction models was well received at the Air Force Space Command at Falcon (AFSPACECOM) and a "steering committee" is being formed to pursue a joint research venture whose details will be outlined in the coming weeks.

PUBLICATIONS: Ross, I.M. and Melton, R.G., "Singular Arcs for Blunt Endoatmospheric vehicle," The Journal of the Astronautical Sciences, Vol. 41, No. 1, pp. 35-51, January - March 1993.

Ross, I.M., "Mutational Stability and Core Energy of a Quasi-rigid Gyrostat," Journal of Guidance, Control and Dynamics, Vol. 16, No. 4, pp. 641-647, July - August 1993.

CONFERENCE PRESENTATIONS: Ross, I. M., "Optimally Pointed Singular Thrust-Laws for Nonlifting Spacecraft," AAS Paper # 93-698, AAS/AIAA Astrodynamics Conference, Victoria, B.C., Canada, 16-19 August 1993.

Ross, I.M., "An Alternative Stability Condition for Dual-Spin Spacecraft," AAS Paper #93-611, AAS/AIAA Astrodynamics Conference, Victoria, B.C., Canada, 16-19 August 1993.

THESES DIRECTED: Hecker, M. A., LCDR, USN, "An Expert System for Processing Uncorrelated Satellite Tracks," Master's Thesis, December 1992.

Wilsey, M. S., LCDR, USN, "A Parametric Analysis of Endoatmospheric Low-Earth-Orbit Maintenance," Master's Thesis, March 1993.

Johnson, R.E., LT, USN, "Effects of Thrust Vector Control on the Performance of the Aerobang Orbital Plane Change Maneuver," Master's Thesis, June 1993.

Henderson, W.K., LT, USN and Neuenfeldt, B.D., LCDR, USN, "A Survey of Uncontrolled Satellite Reentry and Impact Predictions," Master's Thesis, September 1993 (joint thesis).

OTHER: The investigator is working on the following forthcoming publications:

Ross, I.M., Pauls, D.D., and Wilsey, M.S., "Utility of Forced Keplerian Trajectories in Low-Earth-Orbit Maintenance," AIAA/AAS Space Flight Mechanics Meeting, Cocoa Beach, FL, 14-16 February 1994.

Ross, I.M., "A Formulation of Stability Conditions for Systems Containing Driven Rotors," submitted to the Journal of Guidance, Control and Dynamics.

DOD KEY TECHNOLOGY AREA: Design Automation.

KEYWORDS: Singular Arcs, Low-Earth-Orbit Maintenance, Aeroassisted Maneuvers, Trajectory Optimization.

TRANSONIC FAN CASCADE EVALUATION

R.P. Shreeve, Professor

Department of Aeronautics and Astronautics

**Sponsor and Funding: Naval Air Warfare Center,
Aircraft Division (Trenton)**

OBJECTIVE: To develop the means to evaluate blade geometry effects and shock-boundary layer interaction separation-control devices in a fan-passage simulation model. This is a necessary step in the development of more efficient, lighter weight fans for military aircraft.

SUMMARY: A pilot fan-passage simulation model has been built and operated in a small, M=1.4 blow-down cascade wind tunnel equipped with both inlet and back pressure control valves. Instrumentation includes 300 pressure taps over the lower blade section surface and end walls, a pitot survey probe downstream of the blading and shadowgraph-video photography. Flow incidence can be varied through model rotation. Tests have concentrated first on obtaining two-dimensional and periodic flow conditions in two blade passages with normal shocks in their design position, and obtaining repeatability in loss and static pressure distributions. Measurements with low-profile vortex generators are sche-

duled. Nozzle blocks have been designed for M=1.7 and are in manufacture. A test section for tests at larger scale is being designed.

CONFERENCE PRESENTATION: Shreeve, R.P., Myre, D.D., Golden, W.L., Jr., and Collins, C.C., "Simulation of Shock-Boundary Layer Interaction in a Fan Blade Passage," AIAA 93-1980, AIAA/SAE/ASME/ASCE 29th Joint Propulsion Conference and Exhibit, Monterey, CA, 28-30 June 1993.

THESES DIRECTED: Myre, D.D., "Fan Passage Flow Model Simulation," Master's Thesis, December 1992.

Tapp, E., "Development of a Cascade Simulation of Fan Passage Flow," Master's Thesis, December 1993.

DOD KEY TECHNOLOGY AREA: Propulsion and Energy Conversion, Materials and Processes.

KEYWORDS: Shock-Boundary Layer Interaction, Fan Blade Loss Alleviation, Transonic Cascade.

TRANSONIC FAN DESIGN VALIDATION

R.P. Shreeve, Professor

Department of Aeronautics and Astronautics

N.L. Sanger, NASA Lewis Research Center

**Sponsor and Funding: Naval Air Warfare Center,
Aircraft Division (Trenton)**

OBJECTIVE: To replace the single-stage transonic fan currently installed in a test rig at the Turbopropulsion Laboratory with a prototype design recently completed by NASA, and to evaluate all aspects of the aerodynamic performance by the application of advanced intrusive and non-intrusive diagnostics. The project goals are to provide code vs. measurement comparisons to validate current design and analysis codes, to develop practical unsteady measurement diagnostics for use in advanced fan development testing, and to complete a design test and evaluation case study for instructional purposes.

SUMMARY: The aerodynamic design of a

single stage compressor for the NPS test rig was completed and will be reported this year. The mechanical design is also completed and procurement is planned in 1994. The low aspect ratio (1.2) stage has a diameter of 11 inches and tip relative Mach number of 1.3. However, because of unusually high blade loading, the overall stage pressure ratio is projected to be 1.56, at an efficiency of 90%.

DOD KEY TECHNOLOGY AREA: Propulsion and Energy Conversion, Materials and Processes.

KEYWORDS: Transonic Compressor Stage Design.

FAN AND COMPRESSOR STALL AND OFF-DESIGN PERFORMANCE IMPROVEMENT

R.P. Shreeve, Professor

G.V. Hobson, Associate Professor

W.B. Roberts, Flow Applications Research

Department of Aeronautics and Astronautics

Sponsor and Funding: Naval Air Warfare Center,

Aircraft Division (Trenton)

OBJECTIVE: The primary goal is to validate off-design performance and stall prediction for controlled diffusion (CD) compressor blading experimentally and obtain information necessary to enable development of higher blade loading designs.

SUMMARY: Two and three component laser-Doppler velocimetry (LDV), pressure probes, laser-sheet and surface flow visualization techniques are being used to obtain measurements through two designs of CD blading in a large (60 x 10 inch) rectilinear cascade wind tunnel. Measurements are compared with CFD viscous code calculations at progressively increased flow incidence angles. Suction has been installed to control wall boundary layers. First three-dimensional fiber-optic LDV measurements were made successfully and the corner vortices leaving the blading were mapped at eight degrees above design incidence. The high levels of turbulence found near the leading edges of the blading using LDV have been corroborated by recent hot-wire measurements. Refinement of the suction system to reduce inlet boundary layer thickness is planned before the second CD blade design (which has a much higher loading) is installed.

PUBLICATION: Hobson, G.V. and Shreeve, R.P., "Inlet Turbulence Distortion and Viscous Flow Development in a Controlled-Diffusion Compressor Cascade at Very High Incidence," AIAA Journal of Propulsion and Power, Vol. 9, No. 3,

May-June 1993.

CONFERENCE PRESENTATIONS: Moyle, I.N., Shreeve, R.P., and Walker, G.J., "Stator-Relative, Rotor Blade-to-Blade Near-Wall Flow in a Multistage Axial Compressor with Tip-Clearance Variation," AIAA 93-2389, AIAA/SAE/ASME/ASEE 29th Joint Propulsion Conference and Exhibit, Monterey, CA, 28-30 June 1993.

Hobson, G.V., Weber, M.A., and Dober, D.M., "Establishing Two-Dimensional Flow in a Large-Scale Cascade of Controlled-Diffusion Compressor Blades," AIAA 93-2383, AIAA/SAE/ASME/ASEE 29th Joint Propulsion Conference and Exhibit, Monterey, CA, 28-30 June 1993.

THESES DIRECTED: Dober, D.M., "Three-Dimensional Flow Field Measurements in the Endwall Region of a Cascade of Controlled Diffusion Compressor Blades," Master's Thesis, March 1993.

Weber, M.A., "Establishing Two-Dimensional Flow in a Cascade of Controlled Diffusion Compressor Blades with Endwall Suction," Master's Thesis, March 1993.

Wakefield, B.E., "Hotwire Measurements of the Turbulent Flow into a Cascade of Controlled-Diffusion Compressor Blades," Master's Thesis, December 1993.

OTHER: A paper on 3D LDV measurements will be presented at the IGTI Congress at the Hague in June 1994.

DOD KEY TECHNOLOGY AREA: Propulsion
and Energy Conversion, Materials and
Processes.

KEYWORDS: Controlled Diffusion
Blading, Compressor Blade Stall,
Compressor Cascade Wind Tunnel.

**DEPARTMENT
OF
AERONAUTICS AND ASTRONAUTICS**

**1993
Faculty Publications
and Presentations**

JOURNAL ARTICLES

Agrawal, B.N., "Dynamic Characteristics of Liquid Motion in Partially Filled Tanks of a Spinning Spacecraft," AIAA Journal of Guidance, Control, and Dynamics, Vol. 16, No. 4, pp. 636-640, July-August 1993.

Agrawal, B.N., "High Latitude Communications Satellite," Navy Engineer Journal, July 1993.

Angus, W.J., Witt, M.A., Laredo, D., and Netzer, D.W., "Solid Fuel Supersonic Combustion," La Recherche Aerospatiale, 1993-6, pp. 1-8, November-December 1993.

Biblarz, O. and Brown G.S., "Plasma-Sheath Approximate Solutions for Planar and Cylindrical Anodes and Probes," Journal of Applied Physics, Vol 73, No. 12, pp. 8111-8121, 15 June 1993.

Chandrasekhara, M.S., Ahmed, S., and Carr, L.W., "Schlieren Studies of Compressibility Effects on Dynamic Stall of Airfoils in Transient Pitching Motion," Journal of Aircraft, Vol. 30, No. 2, pp. 213-220, March 1993.

Chandrasekhara, M.S. and Ahmed, S., "Velocity and Vorticity Distributions Over an Oscillating Airfoil Under Compressibility Conditions," AIAA Journal, Vol. 31, No.6, pp. 995-996, June 1993.

Ekaterinaris, J.A. and Schiff, L.B., "Numerical Prediction of Vortical Flow over Slender Delta Wings," Journal of Aircraft, Vol. 30, No. 6, pp. 935-942, November/December 1993.

Hebbar, S.K., Platzter, M.F., and Kwon, H.M., "Vortex Breakdown Studies of a Canard-Configured X-31A-Like Fighter Aircraft Model," Journal of Aircraft, Vol. 30, No. 3, p. 405, May-June 1993.

Kaminer, I., Khargonekar, P.P., and Rotea, M.A., "Mixed H_2/H_∞ Control for Discrete Time Systems Via Convex Optimization," Automatica, Vol. 29, No. 1, pp. 57-70, 1993.

Kim, H.-O., Laredo, D., and Netzer, D.W., "Measurement of Submicrometer Al_2O_3 Particles in Plumes," Applied Optics, Vol. 32, No.33, pp. 6834-6840, 20 November 1993.

Laredo, D. and Netzer, D.W., "The Dominant Effect of Alumina on Nearfield Plume Radiation," Journal of Quantative Spectroscopy and Radiative Transfer, Vol. 50, No. 5, pp. 511-530, November 1993.

Ross, I.M. and Melton, R.G., "Singular Arcs for Blunt Endoatmospheric Vehicle," The Journal of the Astronautical Sciences, Vol. 41, No. 1, pp. 35-51, January - March 1993.

Ross, I.M., "Nutational Stability and Core Energy of a Quasi-rigid Gyrostat," Journal of Guidance, Control and Dynamics, Vol. 16, No. 4, pp. 641-647, July - August 1993.

Wood, E.R., Sarigul-Klijn, M., and Kolar, R., "Application of Two Chaos Methods to Higher Harmonic Control Data," Journal of the American Helicopter Society, Vol. 38, No. 2, pp. 68-77, April 1993.

CONFERENCE PUBLICATIONS

Agrawal, B.N. and Bang, H., "Slow Maneuver of a Flexible Spacecraft using On-Off Thrusters," in Proceedings of the AIAA Guidance, Navigation, and Control Conference, AIAA-93-3724, pp. 224-233, Monterey, CA, 9-11 August 1993.

Agrawal, B.N. and Bang, H., "Active Vibration Control of Flexible Space Structures by using Piezoelectric Sensors and Actuators," in Proceedings of the 14th Biennial Conference on Mechanical Vibration and Noise, Albuquerque, NM, pp. 169-179, 19-22 September 1993.

Ball, R.E. and Rainis, A.E., "Live Flight Testing of Military Transport Aircraft; the National Research Council Study and Subsequent DoD Implementation," in Proceedings of the ADPA Transport Aircraft Survivability Symposium, St. Louis, MO, pp. 116-134, 18-21 October 1993.

Biblarz, O. and Riggs, J.F., "Anode Sheath Contributions in Plasma Thrusters," Preprint # AIAA 93-2495, 29th Joint Propulsion Conference and Exhibit, Monterey, CA, 28-30 June 1993.

Chandrasekhara, M.S. and Van Dyken, R.D., "LDV Measurements in Dynamically Separated Flows," in Proceedings of the Fifth International Conference on Laser Anemometry - Advances and Applications, Koningshof, Veldhoven, The Netherlands, SPIE, Vol. 2052, pp. 305-312, 23-27 August 1993.

Clarkson, J.D., Ekaterinaris, J.A., and Platzer, M.F., "Computational Investigation of Airfoil Stall Flutter," in Proceedings of the 6th International Symposium on Unsteady Aerodynamics, Aeroacoustics and Aeroelasticity of Turbomachines and Propellers, Springer Verlag, pp. 415-432, 1993.

Ekaterinaris, J.A. and Platzer, M.F., "Computational Investigation of Unsteady Heat Transfer on Oscillating Airfoils," in Proceedings of the 11th National Heat Transfer Congress, Milano, Italy, pp. 353-363, 24-26 June 1993.

Ekaterinaris, J.A., "Computation of Vortical Subsonic Flows with a High-Order Nonconservative Scheme," AIAA paper 93-3371, AIAA 24th Computational Fluid Dynamics Conference, Orlando, FL, 6-9 July 1993.

Hebbar, S.K., Platzer, M.F., and Liu, D.M., "Effect of Canard Oscillations on the Vortical Flowfield of a X-31A-Like Fighter Model in Dynamic Motion," in Proceedings of the AIAA 11th Applied Aerodynamics Conference, p. 241, August 1993.

Hebbar, S.K., Platzer, M.F., and Li, F.H., "A Visualization Study of the Vortical Flow over a Double-Delta Wing in Dynamic Motion," in Proceedings of the AIAA 11th Applied Aerodynamics Conference, p. 217, August 1993.

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Kaminer, I., Pascoal, A.M., Khargonekar, P.P., and Silvestre, C., "A Velocity Algorithm for the Implementation of Gain-Scheduled Controllers with Applications to Rigid Body Motion Control," in Proceedings of the Conference on Decision and Control, pp. 1043-1048, 1993.

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Newberry, C.F., "Aerospace Design Education (Primarily) at the Graduate Level," Preprint AIAA-93-0329, 31st Aerospace Sciences Meeting and Exhibit, Reno, NV, 11-14 January 1993.

Newberry, C.F., Dober, D.M., Riestler, P.J., Stoney, R.B., Johnston, T.A., and Price, D.R., "Aircraft Design at the Naval Postgraduate School: Tactical Waverider/Long Range Cargo Aircraft," Preprint AIAA-93-4007, AIAA Aircraft Design, Systems and Operations Meeting, Monterey, CA, 11-13 August 1993 [Also, served as the final report for the NPS NASA/USRA Advanced Design Program grant in Aeronautics (Newberry: P.I.)].

Newberry, C.F., Rutherford, and Gouhin, P.J., "National Aerospace Design Competitions: Industry-University Partnerships in Education," in Proceedings of the 1993 Meeting and Conference American Society for Engineering Education (ASEE), Pacific Southwest (PSW) Section, Flagstaff, AZ, 7-8 October 1993.

Newberry, C.F. and Fowler, W.T., "Applied Stability and Control in Aeronautics and Astronautics: Design and Science," Preprint AIAA-93-1079, AIAA/AHS/ASEE Aerospace Design Conference, Irvine, CA, 16-19 February 1993.

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Sivashankar, N., Kaminer, I., and Khargonekar, P.P., "Design of a Controller for the Turret System Using H_∞ Synthesis," in Proceedings of the American Control Conference, San Francisco, CA, pp. 1612-1616, June 1993.

Smith, E.H., Hebbar, S.K., and Platzer, M.F., "Aerodynamic Characteristics of the MMPT ATD Vehicle at High Angles of Attack," in Proceedings of the AIAA 11th Applied Aerodynamics Conference, p. 741, August 1993.

Tuncer, I.H., Ekaterinaris, J.A., and Platzer, M.F., "A Zonal Viscous-Inviscid Interaction Method for 2-D Unsteady, Compressible Viscous Flows," ASME Fluids Engineering Conference, Washington, DC, 20-24 June 1993.

Tuncer, I.H., Ekaterinaris, J.A., and Platzer, M.F., "A Viscous-Inviscid Interaction Method for 2-D Unsteady, Compressible Flows," AIAA paper 93-3019, 24th AIAA Fluid Dynamics Conference, Orlando, FL, July 1993.

Wood, E.R., Sullivan, C.C., and DeMaio, J., "Application of Real-Time Flight Simulation for Design of a Helicopter Obstacle Avoidance System," in Proceedings of the 49th Annual Forum of American Helicopter Society, St. Louis, MO, 18-21 May 1993.

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Agrawal, B.N., "Near-Earth Asteroid Rendezvous," Ninth Annual Summer Conference of the USRA Advanced Design Programs, Houston, TX, 14-17 June 1993.

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Chandrasekhara, M.S., "Oscillating Airfoil Compressible Dynamic Stall," (invited) Institut de Mecanique de Grenoble, Grenoble, France, 30 August 1993.

Chandrasekhara, M.S. and Van Dyken, R.D., "LDV Measurements in Dynamically Separated Flows," Fifth International Conference on Laser Anemometry - Advances and Applications, Koningshof, Veldhoven, The Netherlands, 23-27 August 1993.

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Newberry, C.F. and Fowler, W.T., "Applied Stability and Control in Aeronautics and Astronautics: Design and Science," AIAA/AHS/ASEE Aerospace Design Conference, Irvine, CA, 16-19 February 1993.

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Ross, I.M., "An Alternative Stability Condition for Dual-Spin Spacecraft," AAS Paper # 93-611, AAS/AIAA Astrodynamics Conference, Victoria, B.C., Canada, 16-19 August 1993.

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**DEPARTMENT
OF
COMPUTER SCIENCE**



**Ted Lewis
Chairman**

DEPARTMENT OF COMPUTER SCIENCE

ARTIFICIAL INTELLIGENCE AND ROBOTICS:

In the area of Artificial Intelligence and Robotics, a major research effort is underway in the area of autonomous vehicles (both underwater and above ground) is carried out. Topics such as path planning, sonar data interpretation, graphics simulation, motion coordination, and image understanding are studied. A knowledge-based approaches to the path planning of missile routes that maximize concealment and minimize energy cost is pursued. Also, investigation in the area of intelligent computer assisted military training (e.g. training systems for helicopter recognition and Ada programming) is performed.

COMPUTER GRAPHICS AND VISUAL SIMULATION:

The NPSNET Research Group bases its research around the Naval Postgraduate School Networked Vehicle Simulator (NPSNET). Developed as a student written, real-time networked software running on commercial, off-the-shelf workstations (the Silicon Graphics, Incorporated (SGI) IRIS family of computers), NPSNET was originally envisioned as a low-cost, government owned, workstation-based visual simulator. The project has now evolved to include many facets of virtual reality. The NPSNET Research Group consists of faculty, staff and students developing real-time simulation software, from interfaces to autonomous forces, all within the virtual world of NPSNET. NPSNET-IV.6, the most recent release of our program, is coded in AT&T C++, and continues our commitment to the object-oriented programming paradigm. The simulation reads and writes Distributed Interactive Simulation (DIS) 2.0.3 protocol data units, and utilizes SIMNET and MultiGen formatted terrain and model databases. As a basis for our code, we use an SGI Applications Program Interface (API) called Performer, which handles many of the general purpose processes necessary in a visual simulator, such as hidden surface elimination and culling.

NPSNET research is being conducted entirely within the Department of Computer Science Graphics and Video Laboratory at the Naval Postgraduate School (NPS) as part of the M.S. and Ph.D. programs. NPS was established in 1909 to meet the advanced educational needs of the Navy. The school provides professional studies for military officers of all services and of foreign nations, as well as civilian employees of the U.S. Government. It also supports the Navy and Department of Defense through continuing programs of research and maintenance of expert faculty.

Our research is directly supported by the teaching efforts of the Computer Graphics and Visual Simulation track within the Department of Computer Science. This track (one of six in the department) has a real-time, interactive, three dimensional slant that is particularly conducive to work in the field of virtual worlds.

COMPUTER SYSTEMS AND ARCHITECTURE:

In the Computer Systems and Architecture area, the research is performed in the areas of network communication protocols and VLIW architectures for the next generation of high performance workstations. A progress is made on modeling VSAT networks for communications satellites and on applications of very high speed networks to improve the Navy AEGIS combat system.

DATABASE AND DATA ENGINEERING:

An advanced research effort is being carried out in the areas of interoperable databases, object-oriented databases, and visual querying system. Our current prototype system addresses some of the integration and interoperability issues. We have a kernel database system called Attribute-Based Data Model that is capable of supporting Hierarchical, Network, Relational, Object-Oriented, and Functional Data Model Interfaces. Using our prototype, users can create database hierarchically and access the same database via hierarchical query language or relational query language, for example. In other words, we support a cross-model accessing capability. In addition to the cross-model accessing capability, we are also pursuing to provide a higher level, unified query language. Our approach uses a visual query language to "talk" to different types of databases. The current visual query language is capable of accessing relational databases.

SOFTWARE ENGINEERING:

In the Software Engineering area, the research on Computer-Aided Prototyping System (CAPS) for real-time software, general semantic model for merging changes to software systems, model for the safety-critical multiprocessing aspects of control systems, and model for prototypes of dynamic systems are performed. Fundamental theory and practicing algorithms for the development and management of software systems are actively pursued. A prototype for a low-cost command-and-control system was produced by utilizing the CAPS.

As evident from the above descriptions, the Department of Computer Sciences' research program is highly relevant to the mission of DoN/DoD. Our external funding sources include Naval Research Laboratory, Naval Sea Systems Command, Naval Surface Warfare Center, Naval Weapons Center, NOSC Hawaii, Pacific Missile Test Center, US Army Research Office, US Army Artificial Intelligence Center, US Army Project Manager Training Devices, US Army Test and Experiment Command, US Army AI Center, Ada Joint Program Office, and National Science Foundation. The prototype systems developed under the research programs are actively used in teaching the department's courses and in supporting MS and Ph.D. theses work.

SYNTHESIZING PROGRAMS FROM SPECIFICATIONS

V. Berzins, Professor

Department of Computer Science

Sponsor: Office of Naval Research

Funding: Naval Postgraduate School

OBJECTIVE: Development of reliable programs is a central problem in software engineering. We are investigating automated techniques for generating executable Ada programs from functional specifications. Applications of the resulting technology include software tools for automatic generation of Ada programs, for direct execution of specifications, and for automatically determining whether test results for programs conform to specified functional requirements. Our goal is to develop new technologies for computer-aided design of Ada software systems. A set of software tools for validating requirements and formalizing design efforts of Ada Software Systems are under design and development by applying and extending state of the art research results in software engineering and in artificial intelligence to automate a larger part of the effort in software development. This project emphasizes the refinement of a formal specification tool set suitable for supporting computer-aided development of large Ada programs. To meet urgent needs of DOD, the primary goals of this work are to improve programmer productivity and the quality, reliability, and flexibility of software systems.

SUMMARY: We are investigating mechanisms for using black-box specifications expressed in logic the basis for partial generation of designs and implementations in conventional programming languages such as Ada. We have refined our previous work on developing a formal specification language and explored

the use of formal specifications to support the design of Ada software via case studies. The specification language complements Ada in the design of large systems, and supports descriptions of distributed and real-time systems on a large scale, and is supported by a set of tools for computer-aided software design.

We have investigated the underlying technology needed to create the necessary software tool support for the proposed software development methodology and have surveyed formal methods relevant to providing automated decision support for the design process.

PUBLICATIONS: Berzins, V., "Preface," in Proceedings of the AFOSR/ARO/ONR Workshop on Increasing the Practical Impact of Formal Methods for Computer-Aided Software Development, Monterey, CA, 13-15 October 1993.

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DOD KEY TECHNOLOGY AREA: Software, Computers.

KEYWORDS: Ada, Software Systems.

AUTOMATICALLY COMBINING CHANGES TO SOFTWARE SYSTEMS

V. Berzins, Professor

Department of Computer Science

Sponsor and Funding: U.S. Army Research Office

OBJECTIVE: We seek to develop fundamental theory and practical methods for combining several changes to a software system with mathematically provable guarantees of correctness. The main goal of this research effort is to enable a higher level of computer-aided design in development and maintenance of large software systems. Combining changes to software is a fundamental problem in software engineering. This process is important in all phases of developing large software systems, where multiple changes must be developed concurrently and then combined. This work has potential applications to software maintenance, view integration in specifications, version control in design databases, and multiple inheritance in specification or programming languages.

SUMMARY: We have developed the foundations for a semantic requirements model for general software change merging by showing how to embed a class of domains used in denotational semantics in larger Boolean algebras. We have corrected deficiencies in previous formulations and have extended the results to solutions of reflexive domain equations. We have previously modeled such a semantic operation abstractly, in terms of the operations of a Boolean algebra. The domain construction shows how this model can be applied to a large class of programming languages, and thus provides a precise, language-independent model of the requirements for practical change merging operations.

We have investigated change merging for software prototypes of real-time systems. We are currently addressing problems associated with merging changes to PSDL prototypes. We have been working on an analog of the program slicing method for the PSDL language.

Program slicing has been previously applied to change merging for while programs and we have found that a method applicable to PSDL can be developed based on similar principles despite the fact that PSDL presents new problems because it includes explicit real-time constraints and parallel operations.

Concurrency makes PSDL programs potentially nondeterministic, which requires a substantial rethinking of the previous work that was done in the context of deterministic sequential programs. We have been developing a proof that a slice will exhibit the same behavior regardless of what program it is embedded in. In parallel, we are working out the details of an algorithm for merging changes to PSDL programs whose correctness depends on the behavior invariance theorem.

PUBLICATIONS: Berzins, V. and Yehudai, A., "Using Transformation in Specification-Based Prototyping," IEEE Transactions on Software Engineering, pp. 436-452, May 1993.

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Dampier, D. and Berzins, V., "A Slicing Method for Semantic Based Merging of Software Prototypes," in Proceedings of the 1993 ARO/AFOSR/ONR Workshop on Increasing the Practical Impact of Formal Methods for Computer-Aided Software Development, pp. 21-23, Monterey, CA, October 1993.

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Luqi and Goguen, J., "Some Suggestions for Using Formal Methods in Software Development," in Proceedings of the AFOSR/ARO/ONR Workshop on Increasing the Practical Impact of Formal Methods for Computer-Aided Software Development, Monterey, CA, pp. 7-11, October 1993.

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Berzins, V. and Badr, S., "Robust Scheduling for Large Projects," NPS Technical Report NPS-CS-93-012, December 1993.

Badr and Luqi, "Automation Support for Concurrent Software Engineering," NPS Technical Report NPS-CS-93-013, December 1993.

OTHER: Dampier, D., Luqi, and Berzins, V., "Automated Merging of Software Prototypes," to appear in Journal of Systems Integration, Vol. 4, No. 1, January 1994.

Berzins, V., "Software Merge: Semantics of Combining Changes to Programs," revised for ACM TOPLAS.

DOD KEY TECHNOLOGY AREA: Computers, Software.

KEYWORDS: PSDL, Software.

CHANGE MERGING FOR EVOLUTION OF SOFTWARE PROTOTYPES

V. Berzins, Professor

Department of Computer Science

Sponsor and Funding: U.S. Army Research Office

OBJECTIVE: We seek to explore several aspects of computer-aided software evolution, in support of a main proposal addressing formal models and automated methods for software change-merging. Change merging is the problem of automatically constructing a new version of a program that incorporates the combined effect of several changes to a common base version of the program. The result of an automatic merge must be semantically correct with respect to a realistic formal model of change merging. If an engineer attempts to merge semantically incompatible changes, then a change merging tool should detect and locate the incompatibilities. The project focuses on developing the aspects of change merging technology related to software evolution, software prototyping and software reuse, and for trial application and evaluation of these technologies.

SUMMARY: We have completed a functional specification, design, and implementation for an automated evolution control system. The main advance provided by this system is automated scheduling and job assignment for teams of engineers in

an environment where plans are uncertain, partially known, and subject to change while the work is in progress. We have experimentally determined that a backtracking limit of $0.6N$ on a branch and bound algorithm for nonpreemptive multi-agent scheduling successfully finds all feasible schedules in a moderately sized random sample of scheduling problems, thus providing a practical and highly accurate approximate solution to a NP-hard problem. We have applied heuristic methods to automatically suggest reasonably tight adjustments to project deadlines when the circumstances of the project change to the point where the algorithm cannot find a feasible scheduled.

THESIS DIRECTED: Badr, S., "A Model and Algorithm for Scheduling Software Evolution Steps," Ph.D. Dissertation, December 1993.

DOD KEY TECHNOLOGY AREA: Software.,

KEYWORDS: Software Prototypes, Change.

**DEADLOCK DETECTION IN THE SPECIFICATION OF
DISTRIBUTED C³I SYSTEMS**

V. Berzins, Professor

Department of Computer Science

Sponsor and Funding: Office of the Chief of Naval Operations

OBJECTIVE: The Navy needs to be able to predict if the formal specification of a distributed Command, Control, Communications and Intelligence (C³I) system will permit that system to deadlock. Such a methodology might be used to certify that a distributed C³I system will be deadlock free, prior to the actual development of that system. Deliverables will include the algorithm for deadlock detection in designs of distributed systems.

SUMMARY: Today's C³I systems are no longer single computers, operating in isolation. Tactical command systems now consist of multiple computers networked together. These distributed systems are collections of computers that act like a single machine to their users. Formal specifications can be used to provide a precise 'black-box' description, modeling the intended behavior of these systems, including how the system being described interacts with other systems or the external world.

The issue to be studied was the development of an algorithm and tool that will determine if the specification of a distributed C³I system would permit deadlock to occur in that system when implemented. By determining the deadlock potential of

a system in its formal specification, that specification can be changed prior to actual system implementation, minimizing both operational impact and system development cost. If designs can be certified to be free of potential deadlocks, then system efficiency can be improved by avoiding run-time system monitoring for deadlock detection and transaction roll-back procedures. An algorithm for detecting potential deadlocks from such specifications has been developed.

OTHER: A prototype of a generic C³I station was developed to validate the theoretical results in a practical context. This prototype is implemented in Ada and runs on a commercial workstation (sun 4) under UNIX.

DOD KEY TECHNOLOGY AREA: Computers, Design Automation.

KEYWORDS: C³I.

**SIMULATION AND CONTROL OF AUTONOMOUS
UNDERWATER WALKING ROBOTS**

Y. Kanayama, Professor

R.B. McGhee, Professor

Department of Computer Science

Sponsor and Funding: National Science Foundation (BCS-9109989)

OBJECTIVE: The purpose of this project is to investigate the problems of fast gait control, vehicle dynamics, the effects of ocean currents, and other topics of autonomous underwater walking robots using computer simulation and control of the real robot. This is an international joint project conducted by the Naval Postgraduate School and by the Port and Harbor Research Institute (PHRI) in Japan. The year of 1993 was the second year of the three year period.

SUMMARY: We completed the algorithm investigation and implementation for the Aquarobot graphic simulator including kinematics, inverse kinematics, fast gait planning method, smooth foot trajectory planning, and 3D graphic interface. Dr. Kan Yoneda, Mr. Kenji Suzuki, Mr. John Goetz, Ms. Sandra Davidson, and Mr. Charles Schue were involved in this part of research.

One of the original research problems in the walking robot simulation was gait planning algorithm. Dr. Yoneda, Mr. Suzuki and Prof. Kanayama invented a new algorithm for hexapods called the generalized wavegait planning algorithm. Guaranteeing the maximum duty factor for any given commanded motion, this solution optimizes the robot's stability margins.

Mr. Scott McMillan, Prof. McGhee and others solved the $O(n)$ time linkage dynamics problem (1,2) for the first time extended to the underwater

domain. Hydrodynamic and hydrostatic effects were also included in the method. It is found that the amount of computation required in this case is increased by approximately seventy-five percent over the corresponding requirement for a single chain serial manipulator mounted on a mobile base and operating in space or air.

The idea of this "virtual reality" model is to replace the configuration dependent limb inertias of the above "exact" models with fixed average inertias (including actuators), while computing gravitational, current-induced drag, and hydrostatic forces precisely. As a first step toward a virtual reality model for Aquarobot, we have developed a purely kinematic simulation [4]. This model assumes a level sea bottom, and has proved to be very useful in supporting the development of an initial version of Aquarobot motion coordination software.

One of the goals of this research project is to increase the degree of autonomy of Aquarobot. In particular, we would like to endow this vehicle with a "task-level" control capability. Toward this end, we have developed an innovative control software architecture called the "Rational Behavior Model" (RBM), which incorporates both a goal-directed "strategic" level using logic programming, and a reactive "tactical" level on top of a conventional hard real-time "execution" level. We intend to

pursue an elaboration of the results of using RBM during the third year of this project.

There were frequent visits to and from Japan as a part of our research activities. We invited Mr. Kenji Suzuki, a Ph.D. student at University of Electro-Communications from October 26, 1992 - October 26, 1993. Mr. Hidetoshi Takahashi of PHRI visited NPS from 18-24 January 1993. Prof. Kanayama and Mr. Charles Schue visited PHRI for research discussions from 9-17 April 1993. Dr. Kan Yoneda, Assistant Professor of Department of Mechano-Aerospace Engineering at Tokyo Institute of Technology was invited to NPS for the fast gait planning research (July 1, 1993 - August 31, 1993). Mr. Hidetoshi Takahashi, Mr. Mineo Iwasaki, and Mr. Shigeki Shiraiwa visited NPS for research discussions from 7 September to 4 October 1993.

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Byrnes, R.B., Nelson, M.L., Kwak, S.H., McGhee, R.B., and Healey, A.J., "Rational Behavior Model: An Implemented Tri-Level Multilingual Software Architecture for Control of Autonomous Underwater Vehicles," in *Proceedings of the 8th International Symposium on Unmanned Untethered Submersible Technology*, University of New Hampshire, Durham, NH, pp. 160-178, September 1993.

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Byrnes, R.B., "The Rational Behavior Model: A Multi-Paradigm, Tri-Level Software Architecture for the Control of Autonomous Vehicles," Ph.D. Dissertation, March 1993.

Davidson, S.L., "An Experimental Comparison of CLOS and C++ Implementations of an Object-Oriented Graphical Simulation of Walking Robot Kinematics," Master's Thesis, March 1993.

Grim, C.J., "An Object-Oriented Program Specification for a Mobile Robot Motion Control Language," Master's Thesis, March 1993.

Schue, C.A., "Simulation of Tripod Gaits for a Hexapod Underwater Walking Machine," Master's Thesis, March 1993.

Fish, R.W., "An Expert System for

High Level Motion Control for an Autonomous Mobile Robot," Master's Thesis, June 1993.

MacPherson, D.L., "Automated Cartography by an Autonomous Mobile Robot Using Ultrasonic Range Finders," Ph.D. Dissertation, September 1993.

DeClue, M.J., "Object Recognition Through Image Understanding for an Autonomous Mobile Robot," Master's Thesis, September 1993.

Scott, R.C., "Reengineering Real-Time Software Systems," Master's Thesis, September 1993.

OTHER: Rowe, N.C. and Kanayama, Y., "Minimum-Energy Paths on a Vertical-Axis Cone with Anisotropic Friction and Gravity Effects," accepted by IEEE Journal of Robotics and Automation, December 1993.

McMillan, S., Orin, D.E., and McGhee, R.B., "Simulating Hydrodynamic Effects for Underwater Manipulation," submitted to IEEE Transactions on Systems, Man, and Cybernetics, December 1993.

Kwak, S.H., "Rule-Based Motion Coordination with Utilization of Multiple Programming Paradigms for Walking Vehicles on Ternary-Type Terrain," to be submitted to IEEE Transactions on Systems, Man, and Cybernetics, 1994.

DOD KEY TECHNOLOGY AREA: Design Automation.

KEYWORDS: Robotics, Underwater Robots, Walking Robots, Autonomous Robots, Gait Planning, Rational Behavior Model.

EXPERT SYSTEM FOR PROVISIONING

Y.-J. Lee, Assistant Professor

Department of Computer Science

**Sponsor and Funding: Naval Surface Warfare Center,
Port Hueneme Division**

OBJECTIVE: The major objective of the Expert System for Provisioning (ESP) is to provide the functionalities of an automated system that helps in the process of determining the range and depth of spare and repair parts for U.S. Navy ship weapon systems.

PUBLICATIONS: Dershowitz, N. and Lee, Y., "Logical Debugging," special issue on Automatic Programming, Journal of Symbolic Computation, Vol. 15, Nos. 5 & 6, pp. 745-774, May/June 1993.

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Lee, Y. and Waite, J.V., "Fast Analytical Simulation of Missile Flights," in Proceedings of the Eleventh Annual National Conference on Ada Technology, pp. 8-16, Williamsburg, VA, 15-18 March 1993.

Lee, Y. and Stascavage, J.F., "Multitasking Simulation of a Boiler System Using Qualitative Model-Based Reasoning," ACM Transactions on Modeling and Computer Simulation, special issue on Simulation and AI: Complementary Technologies, Vol. 2, No. 4, pp. 285-306, October 1992.

OTHER: (invited talks) Lee, Y., "Deductive and Inductive Debugging of Logic Programs," at the Department of Computer Science, National Taiwan University, Taipei, Republic of China, 25 June 1993.

DOD KEY TECHNOLOGY AREA: Computers.

KEYWORDS: Expert Systems, Artificial Intelligence, Provisioning.

BUILDING SIMULATIONS OF VIRTUAL ENVIRONMENTS

M. Lin, Assistant Professor

Department of Computer Science

Sponsor and Funding: Naval Postgraduate School

OBJECTIVE: The objective of this research is to address some fundamental problems in dynamic simulation for virtual environments. Our goals are to develop better and more efficient algorithms, reliable software systems, and to demonstrate their applications in virtual environments, such as an immersive training system for Navy officers. The problems include: (1) geometric modeling, (2) interactive collision detection among various objects undergoing physical motion, (3) prompt dynamic response to collision. We will integrate our implementations with NPSNET, a distributed 3D visual simulation system developed in the Department of Computer Science at the Naval Postgraduate School.

SUMMARY: Computer generation of "Virtual Worlds" is concerned with the development of computational models for governing the physical behaviors of objects and the interactions among them. Although substantial work is already done on physical based modeling, there are still areas worthy of much investigation and future improvements. One of them is the ability to detect geometric contacts and respond to these collisions interactively.

As an essential part of the path planner for an autonomous underwater vehicle, it is extremely important to compute the distance between a moving vehicle and its nearby obstacles in order to identify possible geometric collisions and to guide the traveling vehicle safely under the water, before the expensive vehicle is damaged due to unforeseen collisions.

The ability to model deformable objects and their physical behavior can be utilized in various areas, such as rock engineering and mineral technology. Examples include: simulation of soil slippage for computing the force needed in tunnel drilling, creation of a synthetic environment for a combat tank exploring a rocky terrain, etc.

Motivated by these important applications, my present research is centered around interactive dynamic simulations for an immersive training system and obstacle avoidance for military robotics applications. I am especially interested in tackling problems like contact determination and collision response for deformable objects, robot motion planning in a roughly known environment with uncertainty, etc. I plan to build real-time graphical simulation systems for applications in the virtual environments and robotics.

PUBLICATIONS: Lin, M.C. and Canny, J.F., "An Opportunistic Global Planner," in Algorithmica, Special Issue on Computational Robotics, Vol. 10, No. 24, pp. 102-120, August-October 1993.

Lin, M.C. and Manocha, D., "Interference Detection Between Curved Objects for Computer Animation," in Proceedings of the Computer Animation '93, Geneva, Switzerland, June 1993.

Lin, M.C., Manocha, D., and Canny, J.F., "Fast Collision Detection for Geometric Models," Department of Computer Science at the University of North Carolina, Chapel Hill,

Technical Report TR93-004, January 1993.

CONFERENCE PRESENTATIONS: Lin, M.C., Manocha, D., and Canny, J.F., "Real-Time Contact Determination for Geometric Models," Army Research Office and MSI Stony Brook Workshop on Computational Geometry, Raleigh, NC, October 1993.

Lin, M.C., Manocha, D., and Canny, J.F., "Fast Collision Detection for Geometric Models," SIAM Conference on Geometric Design, Tempe, AZ, November 1993.

OTHER: Lin, M.C., "Efficient Collision Detection for Animation and Robotics," Ph.D. Dissertation, U.C. Berkeley, December 1993.

DOD KEY TECHNOLOGY AREA: Design Automation, Human-System Interfaces, Software, Computers.

KEYWORDS: Collision Detection, Dynamic Response, Simulation and Modeling, Synthetic Environments.

FORMAL METHODS FOR SOFTWARE DEVELOPMENT

Luqi, Associate Professor

Department of Computer Science

Sponsor and Funding: U.S. Army Research Office

OBJECTIVE: DoD and industry have an urgent need for software systems that can meet user needs effectively and reliably, and software quality is emerging as one of the main problems for the 1990's. Formal methods that can be partially or completely automated provide a promising approach to solving this problem. A three-day workshop entitled "Formal Methods for Computer Aided Software Development" was held at the Naval Postgraduate School. The purpose of the workshop was to assess current research efforts in this area, to identify results and directions that can increase the degree of automation that is feasible, to aid tool integration by building a common understanding, and to help bring formal methods into practical use.

SUMMARY: Software productivity was a dominant software development problem in the 1980's, and software quality is emerging as one of the main problems for the 1990's. DoD and computer industry have an urgent need for software systems that can meet user needs effectively and reliably. Formal methods that can be partially or completely automated provide a fundamental and promising approach to solve this problem. Formal techniques have influenced the design of languages which are needed for programming-in-the-large and of specification and analysis tools for software engineering. In order to enhance software quality, there is a need for formal methods to play a more prominent role in the software production cycle than has been in the past: for the most part developers are not using formal methods, and researchers have not addressed many

of the issues that arise in large scale applications of formal methods. To achieve this, researchers in formal methods need a better understanding of the aspects of software development in which they can help the developers of large software systems. Software developers need an understanding of the benefits of formal methods, as well as software tools that can apply these methods to the problems that arise in practical software development.

The theme of this workshop was to assess the practical impact of formal methods and tools, identify gaps between the capabilities of formal methods and the needs of practical software development, and define appropriate research directions. The workshop also provided an opportunity to share recent advances in formal methods and tools for many aspects of the software development.

PUBLICATION: Luqi, "Practical Impact of Formal Methods for Computer-Aided Software Development," in Proceedings of the AFOSR/ARO/ONR Workshop, Monterey, CA, 13-15 October 1993.

DOD KEY TECHNOLOGY AREA: Software, Computers, Design Automation.

KEYWORDS: Computer-aided Software, Software Quality, Development.

RAPID PROTOTYPING OF HARD REALTIME SYSTEMS

Luqi, Associate Professor

Department of Computer Science

Sponsor and Funding: National Science Foundation

OBJECTIVE: The goal of this research is to enable rapid prototyping of hard real-time systems via a computer aided prototyping system (CAPS). CAPS is based on a prototyping language with module specifications for modeling real-time systems and combining reusable software. These tools make it possible for prototypes to be designed quickly and to be executed for validating the requirements.

The research focuses on automated methods for retrieving, adapting, and combining reusable components based on normalized module specifications; establishing feasibility of real-time constraints via scheduling algorithms; simulating unavailable components via algebraic specifications; automatically generating translators and real-time schedules for supporting execution; constructing a prototyping project database using derived mathematical models; providing automated design completion and error checking facilities in a designer interface; and establishing a convenient graphical interface for design and debugging.

SUMMARY: Rapid prototyping is a means for stabilizing and validating the requirements for complex systems by helping customers visualize system behavior prior to detailed implementation, e.g. for embedded control systems with hard real-time constraints. CAPS supports an iterative prototyping process characterized by exploratory design and extensive prototype evolution. This should enable the first production version of the software to

match user needs and reduce the need for expensive modifications after delivery. The current version of CAPS has been used to generate a software prototype of a C³I system with hard real-time constraints. The preliminary result of such an approach has shown great promise. It also reveals extreme difficulties in many sub-areas which are due to gaps in the state of the art in many inter-disciplinary subjects of fundamental science. Both theoretical and practical research effort has been devoted with careful strategies in order to make further progress on the subject. The significant and impact of this research to the national economy and to the history of science and engineering makes the success of the project the only possible choice for the researchers.

PUBLICATIONS: Luqi, "Real-Time Constraints in a Rapid Prototyping Language," Journal of Computer Languages, Vol. 18, No. 2, pp. 77-103, Spring 1993.

Berzins, V., Luqi, and Yehudai, A., "Using Transformations in Specification-Based Prototyping," IEEE Transactions on Software Engineering, pp. 436-452, May 1993.

Kraemer, B., Luqi, and Berzins, V., "Compositional Semantics of a Real-Time Prototyping Language," IEEE Transactions on Software Engineering, pp. 453-477, May 1993.

Combelles, A. and Luqi, "Advancing Europe's Fortunes," IEEE Software, pp. 14-20, November 1993.

THESIS DIRECTED: Dolgoff, S.,
"Automated Interface for Retrieving
Software Reusable Components,"
Master's Thesis, September 1993.

DOD KEY TECHNOLOGY AREA: Software.

KEYWORDS: Computer-Aided Software
Engineering, Rapid Prototyping, Hard
Real-Time Embedded Systems.

MODELS FOR PROTOTYPING OF DYNAMIC SYSTEMS

Luqi, Associate Professor

Department of Computer Science

Sponsor and Funding: Naval Surface Warfare Center

OBJECTIVE: This project addresses the development of analytical models of dynamic software systems to support rapid prototyping, computer-aided analysis of hard real-time constraints, and new real-time scheduling methods for dynamic systems. The objective of the proposed research is to enable the design of flexible real-time systems that consist of variable numbers of subsystems whose connection patterns can change with time.

Potential applications include distributed C³I systems and damage tolerant systems that can automatically reconfigure themselves in response to component failures. The results of this research support tools for analyzing hard real-time constraints and synthesizing executable software prototypes.

SUMMARY: The set of subsystems comprising a dynamic system can change with time. Such changes can be due to subsystems physically crossing the boundaries of the dynamic system, such as aircraft entering and leaving a controlled airspace, or due to subsystems failing and coming back on-line after repairs, such as automatically reconfigurable systems designed to survive damage to subcomponents. Embedded software systems are typically subject to hard real-time constraints. However, current approaches to designing real-time systems depend on the assumption that the system structure is static. Our work is developing the basis for removing this restriction.

PUBLICATIONS: Ramesh, B. and Luqi,

"Process Knowledge Based Rapid Prototyping for Requirements Engineering," in Proceedings of the IEEE/ACM Symposium on Requirements Engineering, San Diego, CA, pp. 248-255, January 1993.

Luqi, "How to Use Prototyping for Requirements Engineering," in Proceedings of the IEEE/ACM Symposium on Requirements Engineering, San Diego, CA, p. 229, January 1993.

Dampier, D., Luqi, and Berzins, V., "Automated Merging of Software Prototypes," in Proceedings of the Fifth International Conference on Software Engineering and Knowledge Engineering, San Francisco, CA, pp. 604-611, 16-18 June 1993.

Luqi and Goguen, J., "Some Suggestions for Using Formal Methods in Software Development," in Proceedings of the AFOSR/ARO/ONR Workshop on Increasing the Practical Impact of Formal Methods for Computer-Aided Software Development, pp. 7-11, Monterey, CA, October 1993.

Cooke, D. and Luqi, National Science Foundation, in Proceedings of COMPSAC '93, Phoenix, AZ, 3-5 November 1993.

Luqi, "Models for Prototypes of Dynamic Systems," Final Report FY93, Naval Surface Warfare Center, October 1993.

DOD KEY TECHNOLOGY AREA: Software.

KEYWORDS: Computer-Aided Software Engineering, Rapid Prototyping, Hard Real-Time Embedded Systems.

COMPUTER AIDED PROTOTYPING OF REAL-TIME SYSTEMS

Luqi, Associate Professor

M.-T. Shing, Associate Professor

Department of Computer Science

Sponsor and Funding: Naval Postgraduate School

OBJECTIVE: A computer aided rapid prototyping system to support the development of software systems with hard real-time constraints is especially important for the critical early stages of software design. This research focuses on formal techniques for specifying such complex systems using a Prototype System Description Language and the associated tools for further analysis and design. A major goal of this work is to enable the automation of a larger part of hard real-time software development via execution of real-time prototypes. A special scheme is used to treat the hard real-time constraints and to integrate guidelines beyond conventional compiler technology.

SUMMARY: This project studied automated tools for designing and constructing large real-time software systems. Specific subjects that were addressed include:

1. Providing the conceptual design of CAPS tools, e.g., static scheduler, dynamic scheduler, run-time debugging system, etc.
2. The application of CAPS tools to the specification of real-time systems to establish its ability to handle practical problems.
3. Proposing simplifications and extensions to the PSDL language to improve the treatment of hard real-time constraints.
4. Developing execution support tools to handle a subset of the PSDL language constructs sufficiently rich

to illustrate the feasibility of automatic generation of executable prototypes for the specified systems.

This research uniquely links the two major research flows on modeling of real-time systems and complexity studies on scheduling algorithms in this research area. The hard real-time functional model used and specification based prototyping language provide systematic and unified constructs for modeling, specifying, designing and testing software systems with hard real-time properties.

PUBLICATIONS: Luqi, Shing, M., Barnes, P. and Hughes, G., "Prototyping Hard Real-Time Ada Systems in a Classroom Environment," in Proceedings of the 7th Annual Ada Software Engineering Education and Training Symposium, Monterey, CA, pp. 103-177, 12-14 January 1993.

Badr, S. and Luqi, National Science Foundation, in Proceedings of the Fifth International Conference on Software Engineering and Knowledge Engineering, San Francisco, CA, pp. 225-227, 16-18 June 1993.

Luqi, "Computer-Aided Prototyping - Status and Experiments," in Proceedings of the International Symposium and Workshop on New Models for Software Architecture, Kanazawa, Japan, 8 November 1993.

Badr, S. and Luqi, "Automation Support for Concurrent Software Engineering," NPS Technical Report NPS-CS-93-013, December 1993.

DOD KEY TECHNOLOGY AREA: Software.

KEYWORDS: Computer-Aided Software Engineering, Rapid Prototyping, Hard Real-Time Embedded Systems.

**DEVELOPMENT AND EVALUATION OF A PROTOTYPE
SMALL AUV NAVIGATION SYSTEM (SANS)**

R.B. McGhee, Professor

J.R. Clynch, Research Associate Professor

S.H. Kwak, Research Assistant Professor

Department of Computer Science

Sponsor and Funding: NReD Hawaii

OBJECTIVE: The goal of this project was to construct a breadboard SANS and complete land-based testing using an instrumented golf cart on a calibrated test track. The system to be constructed was intended to demonstrate the feasibility of subsequent development of a wet-test version of SANS in FY94.

SUMMARY: The SANS package is a self-contained unit suitable for accurately determining the location of an autonomous underwater vehicle (AUV) using a combination of GPS, inertial, depth, and magnetic sensors. It also incorporates a computer to provide navigation commands (heading, speed, and depth) to guide the AUV to a mission area, to record mission data, and to return the AUV to its recovery site. It is designed for either internal or external mounting on any AUV, or even for attachment to a human diver. The publications listed below support the conclusion that the location of objects detected by an AUV operating in depths up to 70 meters can be determined to an accuracy of approximately 10 meters rms, worldwide, by a SANS package occupying not more than 120 cu. in., and requiring less than 10 watts average power.

PUBLICATION: Kwak, S.H., Stevens, C.D., Clynch, J.R., McGhee, R.B., and Whalen, R.H., "An Experimental Investigation of GPS/INS Integration for Small AUV Navigation," in Proceedings of the 8th International Symposium on Unmanned Untethered Submersible Technology, Durham, NH, pp. 239-251, 27-29 December 1993.

THESIS DIRECTED: Stevens, C.D., "A Software Architecture for a Small Autonomous Underwater Vehicle Navigation System," Master's Thesis, June 1993.

DOD KEY TECHNOLOGY AREA: Design Automation.

KEYWORDS: Robotics, Minehunting, Autonomous Undersea Vehicles (AUV).

EQUIPMENT FOR OPEN JANUS

D. Pratt, Assistant Professor
B. Lundy, Assistant Professor
Department of Computer Science
Sponsor and Funding: ADPA/ASTO

OBJECTIVE: To develop a distributed simulation system for the National Guard. This system will enhance the warfighting ability of the National Guard by providing them a means to conduct command post exercise from remote locations. By doing this the units leaders can train and develop the command and control practices required to wage a successful campaign.

SUMMARY: This project has just begun, and the bulk of the work will be in 1994, so will be reported fully in next year's summary.

PUBLICATIONS: Lundy, G.M., "Specification and Analysis of a CSMA/CD Protocol Using Systems of Communicating Machines," IEEE Transactions on Communications, March 1993.

Lundy, G.M., "Specification and Analysis of a Composition of Protocols, Information Science, June 1993.

CONFERENCE PRESENTATIONS: Lundy, G.M., "PROTEAN: A Tool for Automated Protocol Analysis," International Conference on Computers and Communications, Scottsdale, AZ, February 1993.

Lundy, G.M., "Mushroom: A Program for the Automated Verification of an SCM Protocol Specification," International Conference on Network Protocols, San Francisco, CA, October 1993.

DOD KEY TECHNOLOGY AREA: Communications Networking.

KEYWORDS: Networks, Simulation, Wargaming, Command and Control.

A FACILITY FOR COOPERATIVE EXECUTION

T.J. Shineall, Assistant Professor

Department of Computer Science

Sponsor and Funding: Naval Postgraduate School

OBJECTIVE: The goal of this research was to model and partially implement a facility for coordinated execution of a long-running non-interactive program during idle periods in workstation usage on a computer network. This coordinated execution is to be performed in a manner that supplies a degree of protection on both the primary user of the workstation and the user responsible for the long-running program.

SUMMARY: Several similar systems were analyzed including LINDA, POLITE and PVM. A common feature of all systems examined was their lack of consideration of the security issues raised by cooperative execution. The common assumption was that the execution would occur in an "open, trusted" environment, where all users had legitimate access to all information on the network and no user would act to corrupt or improperly publish that information. Following this review, a formal specification for the cooperative execution facility was prepared. This specification includes modeling of the coordination and execution portions of the facility as well as formal definition of what security means in this context. The formal specification was reviewed with several computer security experts and revisions were incorporated. Once the specification had been reviewed and revised, development of a prototype facility was performed.

This prototype facility includes only the execution (not coordination) aspects of the facility, but is in a readily extensible form. The facility was validated on a dedicated research network, demonstrating the concept of this type of facility is achievable.

PUBLICATION: Journal publication of this research is in preparation.

THESIS DIRECTED: Busmire, T.E., CAPT, USA, "Concept Definitions and Security Requirements of a Cooperative Execution Environment for Distributed Computing," Master's Thesis, September 1993.

OTHER: CEE - Cooperative Execution Environment - Computer Software.

DOD KEY TECHNOLOGY AREA: Computers, Software, Communications Networking.

KEYWORDS: Computer Security, Computer Networks, Idle-time Computing, Formal Security, Modeling Distributed Software.

A NEW PROGRAMMING LANGUAGE AND ITS ENVIRONMENT

D.M. Volpano, Assistant Professor

Department of Computer Science

Sponsor and Funding: Naval Postgraduate School

OBJECTIVE: The objective of this project is to design, without compromising the security of traditional strong typing, a new more flexible type discipline for a programming environment that supports a novel programming methodology based on data refinement.

SUMMARY: This effort has focused on the design of a new type discipline for performing on-line type inference incrementally in the context of overloading and subtyping. The PI investigated the complexity of type inference in the context of overloading only. A PSPACE lower bound was shown for satisfiability of constraint sets even when overloading is restricted to a very simple form. Two graduate students are separately investigating the on-line and incremental aspects of type inference using attribute grammars. These are two facets of type inference that become important in the environment for this programming language where programs are type checked as they are edited.

PUBLICATION: Volpano, D.M., "Online Polymorphic Type Inference in Polya," in Proceedings of the 4th Navy R&D Information Exchange Conference, Naval Command, Control and Ocean Surveillance Center, RDT&E Division, San Diego, CA, p. 40, April 1993.

CONFERENCE PRESENTATION: Volpano, D.M., "Type Inference in Polya," Naval Ocean Surveillance Center, San Diego, CA, 14 April 1993.

OTHER: Four papers originated from the project during the reporting period, all of which were authored solely by the PI:

"A Critique of Type Systems for Global Overloading," NPS Technical Report NPS-CS-94-002.

"A Lower Bound on Computing the Intersection of Regular Forests," NPS Technical Report NPS-CS-94-001.

"Parametric Overloading and the Computational Complexity of Satisfiability," submitted to the Journal of Functional Programming, December 1993.

Developed the software, using an attributed-evaluator generator, for doing incremental type inference. The system runs under X11R5 and has served as a valuable research prototype.

DOD KEY TECHNOLOGY AREA: Software.

KEYWORDS: Programming Environments, Reliable Software.

RESEARCH IN MULTIMEDIA DATABASE SYSTEMS

**C.T. Wu, Associate Professor
Department of Computer Science
Sponsor and Funding: Naval Ocean Systems Center**

OBJECTIVE: This research is a continuation of a study and development of an intelligent multimedia database management systems. The main objective for this research period is to enhance the prototype.

SUMMARY: One of the proposed interface called DFQL was substantially improved. DFQL is a database query language based on a modified dataflow diagram and relational algebra. The initial DFQL implementation as completely redesigned incorporate an object-oriented design. The translation algorithm that converts a given DFQL query into equivalent SQL statements was enhanced so there will be minimal number of views are created in the backend database.

PUBLICATION: Wu, C.T., "An Integrated Visual Environment for Relational Databases," HCI International Conference, Orlando, FL, August 1993.

CONFERENCE PRESENTATION: Wu, C.T., "An Integrated Visual Environment for Relational Databases," poster presentation at the HCI International Conference, Orlando, FL, August 1993.

OTHER: Wu, C.T., "DFQL: Dataflow Query Language for Relational Databases," to appear in Information and Management.

THESES DIRECTED: MCince, Turgay, LT, Turkish Army, "Design and Implementation of a Query Editor for the Amadeus System," Master's Thesis, September 1993.

Hargrove, J.P., LT, "Design and Implementation of an Interface Editor for the Amadeus Multi-Relational Database Front-End System," Master's Thesis, March 1993.

DOD KEY TECHNOLOGY AREA: Computers, Software, Human-System Interfaces.

KEYWORDS: Database, Query Language, User Interface.

NPSNET AND THE NAVAL POSTGRADUATE SCHOOL
GRAPHICS AND VIDEO LABORATORY

M. Zyda, Professor

D. Pratt, Assistant Professor

J. Falby, Lecturer

P. Barham, Staff

K. Kelleher, Staff

Department of Computer Science

Sponsor and Funding: Naval Postgraduate School

OBJECTIVE: NPSNET-IV is the newest incarnation of the three-dimensional visual simulator developed at the Naval Postgraduate School's Computer Science Department in the Graphics and Video Laboratory. The project centers on the development of graphics simulation software, and will expand to include many facets of virtual reality.

SUMMARY: The Naval Postgraduate School Networked Vehicle Simulator IV (NPSNET-IV) is a low cost, student written, real-time networked vehicle simulator that runs on commercial, off-the-shelf workstations (the Silicon Graphics IRIS family of computers). NPSNET-IV utilizes Simulation Network (SIMNET) databases and SIMNET and Distributed Interactive Simulation (DIS) networking formats. The DIS networking format is flexible enough to allow multiple players to game over the Internet. The availability of NPSNET-IV lowers the entry costs of researchers wanting to work with SIMNET, DIS and follow-on systems. Without the contributions of the department's MS and Ph.D. candidates, the NPSNET project would be impossible to maintain and continue. The diversity of their interests accounts for the broad range of research areas within the project.

PUBLICATIONS: Bhargava, H. and Branley, W., "Simulating Belief Systems of Autonomous Agents," accepted Decision Support Systems,

pending final versions, 1994.

Zyda, M.J., Pratt, D.R., Falby, J.S., Lombardo, C., and Kelleher, K.M., "The Software Required for the Computer Generation of Virtual Environments," accepted by Presence, 7 June 1993 for Vol. 2, No. 2.

Cooke, J.M., Zyda, M.J., Pratt, D.R., and McGhee, R.B., "NPSNET: Flight Simulation Dynamic Modeling Using Quaternions," Presence, Vol. 1, No. 4, pp. 404-420.

Zyda, M., Wilson, K.P., Pratt, D.R., Monahan, J.G., and Falby, J.S., "NPSOFF: An Object Description Language for Supporting Virtual World Construction," Computers & Graphics, Vol. 17, No. 4, pp. 457-464.

Zyda, M.J., Pratt, D.R., Falby, J.S., and Mackey, R.L., "NPSNET: Hierarchical Data Structures for Real-Time Three-Dimensional Visual Simulation," Computers & Graphics, Vol. 17, No. 1, pp. 65-69, 1993.

Zyda, M.J., Osborne, W.D., Monahan, J.G., and Pratt, D.R., "NPSNET: Real-Time Collision Detection and Response," The Journal of Visualization and Computer Animation, special issue on Simulation and Motion Control, Vol. 4, No. 1, pp. 13-24, January - March 1993.

Zyda, M.J., Monahan, J.G., and Pratt, D.R., "NPSNET: Physically-Based Modeling Enhancements to an Object

File Format," chapter in Creating and Animating the Virtual World, Nadia Magnenat Thalmann and Daniell Thalmann, eds., Springer-Verlag, Tokyo, pp. 35-52, 1992.

DeHaemer, M.J. and Zyda, M.J., "Simplification of Objects Rendered by Polygonal Approximations," Computers & Graphics, Vol. 15, No. 2, 1991, Great Britain: Pergamon Press, pp. 175-184. Paper received "Best Paper 1991" award from an international selection committee appointed by the editor of Computers & Graphics, 29 September 1992.

Pratt, D., Zyda M., Falby, J., Amburn, P., and Stytz, M., "NPSNET and AFIT-HOTAS: Interconnecting Heterogeneously Developed Virtual Environments," in "Tomorrow's Realities Gallery," in Proceedings of the Computer Graphics Visual, ACM SIGGRAPH '93.

Zyda, M.J., Lombardo, C., and Pratt, D.R., "Hypermedia and Networking in the Development of Large-Scale Virtual Environments," in Proceedings of the International Conference on Artificial Reality and Tele-Existence, Tokyo, Japan, 6-8 July 1993.

Wilson, K.P., Zyda, M.J., and Pratt, D.R., "NPSGDL: An Object Oriented Graphics Description Language for Virtual World Application Support," in Proceedings of the Third Eurographics Workshop on Object-Oriented Graphics, Champéry, Switzerland, 28-30 October 1992.

Pratt, D.R., Zyda, M.J., Mackery, R.L., and Falby, J.S., "NPSNET: A Networked Vehicle Simulator with Hierarchical Data Structures," in Proceedings of the IMAGE VI Conference, Scottsdale, AZ, 14-17 July 1992.

DOD KEY TECHNOLOGY AREA: Software, Computers.

KEYWORDS: Software, Networking Format.

**DEPARTMENT
OF
COMPUTER SCIENCE**

**1993
Faculty Publications
and Presentations**

JOURNAL ARTICLES

- Berzins, V., Luqi, and Yehudai, A., "Using Transformations in Specifications-Based Prototyping," IEEE Transactions on Software Engineering, pp. 436-452, May 1993.
- Combelles, A. and Luqi, "Advancing Europe's Fortunes," IEEE Software, pp. 14-20, November 1993.
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- Lee, Y. and Dershowitz, N., "Logical Debugging," Special issue on Automatic Programming, Journal of Symbolic Computation, Vol. 15, Nos. 5/6, pp. 745-774, May/June 1993.
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CONFERENCE PUBLICATIONS

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Berzins, V., "Preface," in Proceedings of the AFOSR/ARO/ONR Workshop on Increasing the Practical Impact of Formal Methods for Computer-Aided Software Development, Monterey, CA, 13-15 October 1993.

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Cooke, D. and Luqi, "Formal Support for Software Maintenance," in Proceedings of the COMPSAC '93, Phoenix, AZ, 3-5 November 1993.

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Kanayama, Y., MacPherson, D., and Krahm, G., "Vehicle Motion Control and Analysis Using 2D Transformations," in Proceedings of the IEEE International Conference on Robotics and Automation, Atlanta, GA, 10-15 May 1993.

Lee, Y. and Waite, Y.V., "Fast Analytical Simulation of Missile Flights," in Proceedings of the Eleventh Annual National Conference on Ada Technology, pp. 8-16, Williamsburg, VA, 15-18 March 1993.

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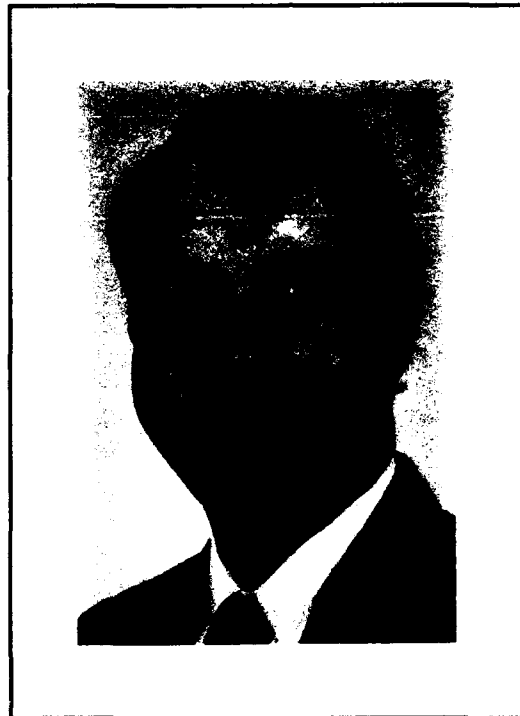
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**DEPARTMENT
OF
ELECTRICAL AND COMPUTER
ENGINEERING**



**Michael A. Morgan
Chairman**

DEPARTMENT OF ELECTRICAL AND COMPUTER ENGINEERING

INTRODUCTION

The research program of the Department of Electrical and Computer Engineering is very broad, reflecting the variety of skills and interests of the faculty in providing technical advances and solutions to important problems for the Department of Defense. DoD Research in ECE is strongly coupled to instruction, both in bringing the most recent advances into the classroom and in providing highly relevant and unique thesis topics for officer students to investigate with faculty guidance.

Research topics span the following areas: Communications, Computer Engineering, Electromagnetics, Electro-Optics, Electronic Systems, Power Systems, Radar and Electronic Warfare, Signal Processing, Systems and Controls, and Underwater Acoustics. The following compendium categorizes each research project into one of the above areas. Some research projects involve one or more of these areas, although they are listed here in only one category. There is a strong interaction between the department's teaching and research programs, both by the incorporation of the latest research into courses and by the involvement of graduate students in the projects, as indicated by the numbers of theses completed.

COMMUNICATIONS

SIGNAL-TO-NOISE ENHANCEMENT PROGRAM (SNEP) **RESEARCH AND SUPPORT**

R.W. Adler, Senior Lecturer
D.Z. Wadsworth, Senior Lecturer
W.R. Vincent, Senior Researcher
Department of Electrical and Computer Engineering
Sponsor and Funding: COMNAVSECGRU

OBJECTIVE: Continued research and development in techniques to improve the signal-to-noise ratio at Navy receiving sites worldwide.

SUMMARY: Development of techniques and methodology for identifying and locating radio noise sources at NSG sites worldwide continued. The initial version of the Automated Performance Evaluation Technique for HF receiving sites was completed. Support was provided to NGS via review of pre-survey planning documentation, mitigation plans and authoring "Quick-Look" and final site-survey reports. Students and NSG site personnel were trained as part of the NSG support. A 2 1/2 day HF technical review of Factors that Affect Performance of Naval Receiving Sites was hosted for CNSG.

PUBLICATIONS: Two Conference Papers, three Technical Reports, and nine Conference Presentations. Two MS Theses were produced.

DOD KEY TECHNOLOGY AREA: Sensors.

KEYWORDS: Electromagnetic environmental effects, communication systems, man-made noise.

**COMMUNICATION SYSTEM PERFORMANCE EVALUATION AND
HIGH LATITUDE PROPAGATION RESEARCH**

R.W. Adler, Senior Lecturer

W.R. Vincent, Senior Researcher

Department of Electrical and Computer Engineering

Sponsor and Funding: COMNAVSECGRU

OBJECTIVE: The goal of this sixth year of a continuing project was to conduct numerical analysis and experimental research in support of the Navy's requirement to site VLF through UHF communication antenna systems and support equipment in non-ideal locations such as polar and equatorial regions containing rugged terrain. A program of support for investigating the radiowave propagation characteristics of the polar (high-latitude) and the equatorial ionosphere was initiated in 1990 and continued in 1993.

SUMMARY: During this sixth year of the effort numerical models of antennas were developed for use at a new NSGD site in Shemya, AK. The electrical characteristics of the earth at several dozen NSG sites were measured and used to predict the effect of the ground beneath antennas deployed at the sites. Numerical models of commercial and NPS-built HF receiving antennas were developed and used to provide gain values for an ionospheric field strength model. Selected HF ionospheric propagation prediction codes were evaluated and compared to measured data for polar regions. NPS has been selected as the agency to oversee the development of theoretical and numerical models for the effects of irregular terrain on the performance of HF and VHF antennas. Penn State, LLNL, and NPS are in the last year of development of different types of terrain effects models. This project will integrate these models into the tri-service RF Mission Planning Workstation, being developed by the sponsor. A three-day conference on Trans-Equatorial and Near-Equatorial Propagation was hosted at NSP in June 1993 for CNSG.

PUBLICATIONS: The research produced one conference paper, three technical reports and two MS theses.

DOD KEY TECHNOLOGY AREA: Sensors, Environmental Effects.

KEYWORDS: Electromagnetic environmental effects, communication systems, man-made noise, antennas, radiowave propagation.

FIELD STATION RESEARCH AND SUPPORT

R.W. Adler, Senior Lecturer
W.R. Vincent, Senior Researcher
D.Z. Wadsworth, Senior Lecturer
Department of Electrical and Computer Engineering
Sponsor and Funding: U.S. Army INSCOM

OBJECTIVE: The Army's SIGINT sites in Korea were subjected to an investigation by the NPS Signal Enhancement Lab staff to assess performance and to identify factors that were degrading performance.

SUMMARY: The Army's Field Station KOREA Tactical SIGINT site at Camp Humphrey required a thorough site performance investigation. NPS used techniques developed for the Naval Security Group HFDF sites to identify the key factors of the installation that must be addressed if site performance is to be restored and maintained. One of the three DMZ detachments was also visited by the NPS team to assess the state of performance and identify factors that degraded performance. Recommendations for mitigation of noise sources which were located was made.

PUBLICATIONS: The research resulted in one technical report and three MS theses.

DOD KEY TECHNOLOGY AREA: Sensors.

KEYWORDS: Electromagnetic environmental effects, communication systems, man-made noise.

PANSAT COMMUNICATIONS SYSTEM DESIGN

Tri T. Ha, Professor
Department of Electrical and Computer Engineering
Sponsor and Funding: SPAWAR 40, Naval Postgraduate School

OBJECTIVE: The purpose of this research project is to design and build a breadboard direct sequence spread spectrum transreceiver for the Petite Amateur Navy Satellite (PANSAT).

SUMMARY: A direct sequence spread spectrum (DSSS) transreceiver for PANSAT was designed and was built. The transreceiver was designed to operate at 9600 bps and has a pseudo-noise (PN) sequence length of 127. The system consists of six boards. Board 1 is the transceiver front-end. Board 2 contains IF and detection circuits. Board 3 is the receiver tracking circuit. Board 4 is the BPSK demodulator. Board 5 is the BPSK modulator. Board 6 contains the PN generator and differential encoder. Additionally, Board 6 acts as the interface between the transreceiver and the digital control system.

PUBLICATIONS: Three theses were produced.

DOD KEY TECHNOLOGY AREAS: Communications, networking

KEYWORDS: Direct sequence spread spectrum

**SEQUENTIAL ACQUISITION SCHEMES FOR SSMA SYSTEMS WITH
GENERALIZED SIGNATURE SEQUENCES**

Alex W. Lam, Associate Professor
Department of Electrical and Computer Engineering
Sponsor and Funding: Army Research Office

OBJECTIVE: The goal of this project was to investigate fast sequential acquisition schemes and system performance of spread-spectrum systems with complex signature sequences.

SUMMARY: This continuing research was to investigate sequential code sequence acquisition schemes for spread-spectrum multiple-access communications systems with generalized signature sequences. Fast, robust sequential code sequence acquisition schemes were developed and analyzed for systems with or without the presence of data modulation. Parametric and nonparametric schemes were proposed. Noncoherent and M-ary digital modulations were employed together with the generalized (nonbinary and polyphase) sequences. Product sequences that were efficient for rapid multiple-level sequential and/or parallel detections were proposed. The results were essential to the understanding of the system efficiency and reliability.

PUBLICATIONS: The research produced two conference papers and one thesis.

DOD KEY TECHNOLOGY AREA: Communications Networking.

KEYWORDS: Spread spectrum, sequential, sequence acquisition, CDMA.

DEVELOPMENT OF PROTOCOLS FOR MARITIME MOBILE COMMUNICATIONS

R. Clark Robertson, Associate Professor
Tri T. Ha, Professor
Department of Electrical and Computer Engineering
Sponsor and Funding: U.S. Coast Guard Research and
Development Center

OBJECTIVE: The purpose of this research program is to determine what Open System Interconnection (OSI) data communication protocols can be used to provide effective and efficient data communications for radio-based maritime mobile services (including satellite systems).

SUMMARY: Data communications are becoming more extensively used in the maritime mobile services. With no current general protocol profile that can be used for data communications between mobile services, protocols that adhere to the OSI standards need to be developed. The implementation of such protocols will allow multiple shipboard equipment to communicate via a shipborne network and then

transmit the data to a shore-based network in an efficient manner. Automatic Repeat reQuest (ARQ) techniques are often used by packet switching networks to provide error free communication links between network nodes. Information throughput is highly link dependent; as the noise or interference on the link increases, throughput decreases. To improve throughput on a packet switching communications network, an adaptive ARQ strategy was developed and applied to the Stop-and-Wait (SW) protocol. A comparison of the throughput efficiencies of the simulated adaptive SW protocol with the non-adaptive SW protocol shows a marked improvement in throughput when the communication links are subjected to high channel bit error rates.

PUBLICATION: One technical report was produced.

DOD KEY TECHNOLOGY AREA: Communications Networking

KEYWORDS: Open System Interconnect (OSI), protocols, data communications network

PERFORMANCE OF FAST FREQUENCY-HOPPED
M-ary FREQUENCY-SHIFT KEYING SYSTEMS OVER
FADING CHANNELS WITH PARTIAL-BAND INTERFERENCE
R. Clark Robertson, Associate Professor
Department of Electrical and Computer Engineering
Sponsor and Funding: Naval Postgraduate School

OBJECTIVE: The goal of this project is to determine the Electronic Counter-Counter Measures (ECCM) potential of various FFH/MFSK communications systems under conditions of worst case hostile Electronic Counter Measures (ECM) and fading channels.

SUMMARY: The performance of an M-ary orthogonal frequency-shift keying (MFSK) communication system employing fast frequency-hopped spread spectrum waveforms transmitted over a frequency-nonselective, slowly fading channel with partial-band interference was analyzed. A procedure referred to as noise-normalization combining was employed by the system receiver to minimize partial-band interference effects. Each hop was assumed to fade independently. The partial-band interference was modeled as a Gaussian process. Both the signal and the partial-band interference were assumed to be affected by the fading channel which was modeled as Rician. The effect of fading of the partial-band interference on worst-case receiver performance was relatively minor. When there was no signal fading or when the signal fading was Rician, then the counter-intuitive result of poorer receiver performance when the partial-band interference experienced fading was obtained. This effect was most pronounced when the signal did not fade and the partial-band interference experienced Rayleigh fading.

PUBLICATION: The research produced one conference paper.

DOD KEY TECHNOLOGY AREA: Other.

KEYWORDS: Spread spectrum, fast frequency-hopping, partial-band interference.

COMPUTER ENGINEERING

DIGITAL SYSTEM DESIGN USING MULTIPLE-VALUED LOGIC

J.T. Butler, Professor

Department of Electrical and Computer Engineering

Sponsor and Funding: Naval Postgraduate School

OBJECTIVE: This project is directed toward the development of computer-aided design tools for multiple-valued circuits. Specifically, our effort is directed to further developing the simulated annealing technique, a search technique that can potentially produce exact designs, unlike heuristic approaches proposed by other researchers.

SUMMARY: Significant progress was made in four areas: 1. extension of the simulated annealing technique, 2. use of feedback in improving combinational logic circuit design 3. use of the pseudo-Kronecker expansion for use in designing field-programmable logic arrays, and, 4. use of the universal literal for programmable logic array implementation.

Our present work on simulated annealing showed that this technique has significant promise in designing multiple-valued programmable logic arrays (MVL-PLA) [Butler, 1993]. An important benefit was the potential for finding the minimal size MVL-PLA in every case, a quality not shared by any other known approach. Our experimental results confirmed that it produced more efficient designs than any other known approach. However, simulated annealing is a search. We developed our algorithm so that the search could be conducted by multi-processors, and showed the relative merit of various numbers of processors [Yildirim, Butler, and Yang, 1993]. In conventional simulated annealing, there is the possibility that the search will occur repeatedly the same part of the search space. To avoid this, we developed an algorithm that used history to decide on directions of search, and programmed it so that it would tend to move away from regions already searched. This is called a "tabu" search, because it labels as tabu moves that would take it to regions already visited. The result showed that we could either produce better results in the same time as classical simulated annealing or we could obtain comparable results in a shorter time.

A very interesting discovery was that feedback in combinational logic circuits could be used to significantly reduced circuit complexity in multiple-valued circuits [Butler and Sasao, 1994]. Feedback is commonly used in sequential circuits, circuits that "remember" past inputs. Most design engineers associate feedback only with sequential circuits. Our discovery was that feedback could be used to significantly reduce the complexity of multi-output circuits. Specifically, we showed a combinational circuit that had only six gates with feedback, while the same combinational circuit without feedback requires at least ten gates. We are very interested in pursuing this result to better understand it, so as to make it useful in Navy computing applications.

We have begun to study the design of field programmable gate arrays (FPGA's). Such devices have potentially better density capability than PLA's. We show an algorithm for the generation of near-minimal designs that uses the Kronecker representation [Sasao and Butler, 1994].

In another effort, we showed that the use of the universal literal requires significantly smaller PLA area than the use of conventional "window" literals [Dueck and Butler, 1994].

PUBLICATIONS: The research produced one journal article, two conference papers, three accepted conference papers for 1994, and one MS thesis.

DOD KEY TECHNOLOGY AREA: Computers, Computer-aided design.

KEYWORDS: multiple-valued logic, computer-aided design, programmable logic arrays, field programmable gate arrays.

**RADIATION TOLERANT, HIGH-SPEED,
LOW-POWER, GALLIUM ARSENIDE DYNAMIC LOGIC**

Douglas J. Fouts, Assistant Professor
Department of Electrical and Computer Engineering
Sponsor and Funding: SPAWAR

OBJECTIVE: Gallium Arsenide (GaAs) digital logic is now the technology of choice for high-performance, terrestrial-based computers and digital systems. Furthermore, research has shown that GaAs ICs are inherently hard against long-term exposure to high levels of ionizing radiation. This tends to make GaAs logic ideal for use in high-performance, space-based computers and digital systems. However, GaAs logic suffers from single event upset (SEU) problems in high radiation environments. The purpose of this three-year project is to study and quantify the SEU problem in GaAs logic, and to develop SEU-tolerant logic circuits. The effort is concentrating on dynamic logic, such as Two Phase Dynamic FET Logic (TDFL), because of its lower power consumption compared to static logic.

SUMMARY: Custom hardware for conducting radiation-induced, single even upset testing of GaAs dynamic logic has been designed, constructed, debugged, and tested. The hardware has been used to test existing GaAs dynamic logic circuits, especially Two-Phase Dynamic FET Logic (TDFL), for susceptibility to SEUs. With this information, predictions have been made about the error rate for GaAs dynamic logic circuits in a spacecraft in a geosynchronous orbit of approximately 22,500 miles. The initial testing phase of the project is now complete. Results indicate that GaAs TDFL has about the same sensitivity to SEUs, or is perhaps a little less sensitive, than the more common forms of GaAs static logic, such as Directly-Coupled FET logic (DCFL). This is a significant result because prior to this research, it was assumed that dynamic logic was more sensitive to SEUs than static logic. GaAs dynamic logic can now be used in place of GaAs static logic in new spacecraft systems, which will result in a significant power saving while maintaining high speed operation. The preferred method for

increasing SEU tolerance is to change the logic circuit at the transistor level by utilizing techniques such as redundancy. This frees the logic designer and the system architect from having to worry about SEUs, and is also less expensive than alternate methods, such as modifying the fabrication process to reduce transistor vulnerability. Therefore, ongoing research is attempting to develop dynamic logic circuits that are even more tolerant of the transient errors caused by SEUs. New, experimental GaAs logic circuits have been designed, and their operation has been simulated. A new, full custom, SEU test and evaluation IC has been designed and implemented, and is currently being fabricated. The purpose of the test and evaluation IC is to provide a method for evaluating the characteristics of the new logic circuits, both under normal environmental conditions and under radiation.

PUBLICATIONS: Two MS theses have been produced.

OTHER: The primary research output from this project has been custom hardware for conducting radiation-induced single event upset testing of GaAs dynamic logic. Also, in addition to the journal publication and the two related theses, bimonthly progress reports have been written and forwarded to the contract monitor. Several of these progress reports have been supplied, by request, to an industrial corporation, and the results of this research have already been incorporated into the design of a new NASA satellite.

DOD KEY TECHNOLOGY AREA: Computers.

KEYWORDS: Radiation hard electronics, high-speed computing, space electronics.

HIGH PERFORMANCE COMPUTING TECHNOLOGY FOR
NAVY DIGITAL SIGNAL PROCESSING

Chin-Hwa Lee, Professor

Department of Electrical and Computer Engineering

Sponsor and Funding: Naval Postgraduate School

OBJECTIVE: In this project a typical Navy digital signal processing (DSP) problem is run on a high performance parallel system. The goal is to develop a top down design methodology to partition a DSP problem into massively interconnected modules (MIM). We use the VHDL language to formulate the MIM modules so that algorithm decomposition were checked automatically.

SUMMARY: Beam Forming problems for acoustic signal detection were used as an example to develop the computation loads metrics. These metrics included computation bandwidth, communication bandwidth, memory bandwidth, FLOPS-IO ratio, and Latency-FLOPS product. Estimates of these metrics were useful in decomposing the total DSP tasks. From the software and hardware point of views, parallel systems with message

passing were the most attractive approach for parallel processing. A demonstration was developed to show this design approach.

PUBLICATIONS: The research produced a workshop paper, a conference presentation, and a thesis.

DOD KEY TECHNOLOGY AREA: Software

KEYWORDS: High performance computing, digital signal processing, beam forming.

MASSIVELY PARALLEL SYSTEM DESIGN

Chin-Hwa Lee, Professor

Department of Electrical and Computer Engineering

Sponsor and Funding: Naval Surface Warfare Center,
Dahlgren Division, White Oaks Detachment

OBJECTIVE: The objective of this proposal is to showcase the systems engineering methodologies developed under the Systems Engineering Block. This goal is accomplished by assessing the fundamental tradeoff between development cost, life cycle cost, time and performance for a beamforming implementation problem. This tradeoff analysis concentrates on using the specific metrics formulated by the Systems Engineering Block.

SUMMARY: The Wide Aperture Array (WAA) served as a showcase for the application of the methodologies developed in the Systems Engineering Block. The large number of hydrophones in the array requires approximately 15 GFLOPS of sustained throughput for full detection capability. Efficiency, latency, performance monitoring and fault localization (PMFL), and real-time operating system overhead could establish a 100 GFLOP peak throughput requirement. These attributes enable the Wide Aperture Array in-board functions to serve as a showcase for the methodologies developed by the Systems Engineering Block to assess and model real-time complex computer systems. In this research a Calibrated Mapping Performance Paradigm (CMPP) was developed to evaluate the partition results. Preliminary result is promising.

PUBLICATIONS: The research produced two conference papers.

DOD KEY TECHNOLOGY AREA: Software.

KEYWORDS: High performance computer, digital signal processing, beam forming.

PROJECT GUSTY ORIOLE

H. H. Loomis, Jr., Professor

R. Bernstein, Instructor

Department of Electrical and Computer Engineering

Sponsor and Funding: Secretary of the Air Force

OBJECTIVE: To conduct research into computer algorithms and architectures for the processing of tactical information. To provide support for the course Space Systems 3001, Military Applications of Space.

SUMMARY: Investigated Algorithms and architectures of systems for the production, distribution and analysis of tactical information. Investigated architectures of spaceborne computer systems. Investigated operational problems concerned with the employment of tactical information for decision making and targeting. Continued research into chokepoint shipping analysis. Visited several military satellite facilities to gather information in support of SS3001.

PUBLICATIONS: Three theses were produced.

DOD KEY TECHNOLOGY AREA: Computers.

KEYWORDS: Military space, chokepoint, shipping monitoring, tracking and correlation.

COMPILE-TIME SUPPORT FOR THE PROCESSING GRAPH METHODOLOGY

ON THE AN/UYS-2 PARALLEL SIGNAL PROCESSOR

Shridhar B. Shukla, Assistant Professor
Department of Electrical and Computer Engineering
Amr Zaky, Assistant Professor
Department of Computer Sciences
Sponsor and Funding: Naval Sea Systems Command

OBJECTIVE: The goal of this continuing project is to develop a methodology for determining the optimal chains of primitives in processing graph methodology (PGM) applications running on the AN/UYS-2.

SUMMARY: Performance of the AN/UYS-2 can be improved if the primitives of the PGM graph are chained together appropriately. In order to construct the best possible chains automatically instead of manually, a framework, based on a technique called revolving cylinder scheduling, was developed. This technique is based on mapping the graph at compile-time on a cylinder whose curved surface area is determined by the number of processors and graph characteristics such as primitive computation times and data arrival rate. The potential of this technique for chaining as well as for predictable execution was demonstrated by building a simulator for the AN/UYS-2. Work is in progress to determine the feasibility of deploying this technique in the actual AN/UY-2 programming environment. Two theses have been completed and three more are in progress as part of this work.

PUBLICATIONS: Research produced one conference paper (won the Outstanding Paper Award) and four MS theses.

DOD KEY TECHNOLOGY AREA: Computers.

KEYWORDS: Real-time, signal processing, parallel processing.

**DESIGN AND PERFORMANCE CHARACTERIZATION OF A
MULTIPURPOSE DECENTRALIZED GROUP MEMBERSHIP SERVICE**

Shridhar B. Shukla, Assistant Professor
Department of Electrical and Computer Engineering
Sponsor and Funding: Research Initiation Program,
National Science Foundation

OBJECTIVE: The goal of this three-year project is to develop and characterize a multi-purpose and scalable group membership service.

SUMMARY: This project focuses on the structure of a group membership service, a basic building block for group-oriented distributed applications. The objectives of this project are development and performance characterization of a membership service with multiple classes of service. The emphasis is on categorical definition of service classes to support a wide spectrum of applications, adaptive status monitoring to minimize wrongly perceived status changes, a completely decentralized and hierarchical protocol requiring an overhead proportional to the quality of the service rendered, and support of a spectrum of membership semantics in spite of transient network partitioning. Techniques will be developed to support seamless distribution of large groups across a set of heterogeneous networks by exploiting the attributes of local communication environments and using topology-based optimizations. Formal techniques will be used for specification, verification, and implementation of the protocol. A performance metric will be developed for characterization of the performance of membership protocols. Performance will be studied with simulations based on stochastic modelling of applications, membership protocols, and underlying networks. The simulations will be built using commercial network engineering tools. The main contributions expected from this research are a single multipurpose membership protocol instead of the current application-specific variety and quantitative performance characterization which is currently lacking.

PUBLICATIONS: Two theses were produced.

DOD KEY TECHNOLOGY AREA: Communications Networking.

KEYWORDS: Reliable, distributed, membership.

ELECTROMAGNETICS

STUDY OF WIDEBANDING TECHNIQUES FOR VHF ANTENNAS

Ramakrishna Janaswamy, Associate Professor
Department of Electrical and Computer Engineering
Sponsor and Funding: U.S. Army Communication and
Electronics Command

OBJECTIVE: To investigate new techniques for widebanding VHF wire antennas over

the frequency range 30--90MHz for digital radio applications.

SUMMARY: In the second year of this two-year project, feasibility studies were carried out for converting a simple monopole antenna into a wideband device capable of operating at any frequency in the 30--90 MHz range. Interest was in frequency agility rather than in wide instantaneous bandwidth. Two schemes were evaluated. In the first scheme, a simple monopole antenna operating over a ground plane was loaded with fast switching PIN diodes. The physical length of the monopole could be varied by selectively switching ON or OFF the PIN diodes to present approximately the same electrical length over the entire frequency band. In the second scheme, a fixed length monopole antenna connected to parallel configuration of several matching networks which could be tuned electronically was considered. The matching networks, switched selectively, render the input impedance as well as the radiation pattern of the antenna relatively insensitive to frequency. Overall efficiency of the antenna, including the insertion losses of the PIN diodes, current flow through the diodes, input impedance of the antenna, and radiation pattern of the antenna were all computed using an integral equation technique.

PUBLICATIONS: The research produced two technical reports and one master's thesis.

DOD KEY TECHNOLOGY AREA: Sensors.

KEYWORDS: Antennas, broadbanding techniques.

COMPUTER MODEL FOR PROPAGATION OVER IRREGULAR TERRAIN

Ramakrishna Janaswamy, Associate Professor

Department of Electrical and Computer Engineering

Sponsor and Funding: Naval Security Group Support Activity

OBJECTIVE: To develop a computer model for predicting HF wave propagation over two and three dimensional terrain for siting antenna systems under varying terrain situations.

SUMMARY: In the second year of this two-year project, we have developed a computer model of electromagnetic wave propagation over lossy, irregular terrain. Finite differences together with near-field radiation conditions were used to result in a rapid model whose execution time is of order $O(N)$ and whose storage requirement is of order $O(N^2)$. Half-space Green's function is used to further reduce the computational domain. The code computes the ground wave attenuation as well as sky wave patterns for an arbitrarily polarized, two dimensional current element in the presence of irregular and inhomogeneous terrain. The code is capable of handling huge terrain irregularities extending a few hundred wavelengths where other methods tend to be inefficient.

PUBLICATIONS: As a result of this research, a technical report has been produced, and a journal article and two conference papers have been submitted for publication.

DOD KEY TECHNOLOGY AREAS: Design Automation, Environmental Effects.

KEYWORDS: EM wave propagation, computational electromagnetics.

FIELD CANCELLATION USING A COUNTER-EMF APPROACH

Michael A. Morgan, Professor and Chairman
Department of Electrical and Computer Engineering
Sponsor and Funding: Naval Postgraduate School

OBJECTIVE: This two-year project investigates a practical approach for reducing bistatic radar cross section using active cancellation.

SUMMARY: The counter-EMF technique appears most promising at radar frequencies below which passive measures such as shaping and absorbing materials are inoperative. Thus the active approach may dovetail in frequency with the more conventional methods to provide ultra-wideband RCS reduction against future radar designs, including impulse radars. The first year has been devoted to analytical studies and numerical simulations to consider tradeoffs of RCS reduction vs. frequency range for number and placement of canceler modules using wire models of aircraft structures. Typical bistatic RCS reductions of at least 20 dB over all aspects are observed around frequencies corresponding to canceler spacings of one-fourth wavelength. Reductions of 30-40 dB are observed for still lower frequencies. Gradual degradation of performance is observed as frequency is increased until canceler spacing approaches one-half wavelength, at which point the system fails dramatically. The second year will provide more detailed numerical modeling and begin to design scale model experimental validations.

PUBLICATION: A journal article is in preparation.

DOD KEY TECHNOLOGY AREA: Sensors.

KEYWORDS: Active cancellation, RCS reduction, low observables.

ULTRA-WIDEBAND IMPULSE ANTENNA DESIGN

Michael A. Morgan, Professor and Chairman
R. Clark Robertson, Associate Professor
Department of Electrical and Computer Engineering
Sponsor: U.S. Army CECOM Signals Warfare Directorate

OBJECTIVE: Goals of this project are to conduct engineering designs, develop test procedures, and to construct and test prototypical ultra-wideband impulse receiving antennas.

SUMMARY: Impulse antennas are antennas that are intended to either transmit or receive very short pulses of electromagnetic energy. As is well known, short pulses have extremely wide bandwidths; hence, impulse antennas by their very

nature must be wideband. However, in order to maintain signal fidelity, it is also very important that the impulse antenna not introduce significant phase distortion into the signal. What is required is a wideband antenna with not only a constant magnitude response across the bandwidth but also linear phase shift resulting in minimal dispersion of the signal. Research into impulse antennas has been very intense for a number of years now, with a major application being the measurement of EMP signals resulting from nuclear explosions. A TEM horn antenna for receiving impulse signals with a theoretical bandwidth of 100MHz--5GHz was designed, constructed and tested in 1993. Follow-on work planned in 1994 will consider designs for increasing antenna gain and bandwidth, while reducing the physical size of the antenna structure.

PUBLICATIONS: The research produced a technical report and two conference papers.

DOD KEY TECHNOLOGY AREA: Sensors.

KEYWORDS: Ultra-wideband, impulse antennas, TEM horns.

**EVALUATION OF ANTENNA CHARACTERISTICS BASED ON
AVAILABLE INFORMATION**

R. Clark Robertson, Associate Professor
Department of Electrical and Computer Engineering
Sponsor and Funding: Naval Maritime Intelligence Center

OBJECTIVE: The purpose of this research program was to develop a set of user friendly mathematical applications capable of computing the radiation pattern and other pertinent antenna parameters of an antenna or antenna system based available information.

SUMMARY: It is important to be able to obtain as specific an idea as possible of the capabilities, limitations, and vulnerabilities of a particular antenna or antenna system. Oftentimes, the only information available is that of a photograph of the system under investigation and the physical size of the system. Generally, this will primarily be information obtained from a photograph and the physical dimensions of the antenna or antenna system; although, the applications are flexible to the extent that they make their computation based on whatever information is available. The mathematical applications are designed to be operated by an engineer familiar with basic antenna types. All mathematical applications are based on existing engineering equations for the antenna type under consideration. A number of applications for various antenna types have been completed.

PUBLICATIONS: The research produced two technical reports and two master's theses.

DOD KEY TECHNOLOGY AREA: Sensors.

KEYWORDS: Antenna, radiation pattern, antenna gain.

EMP WAVEFORM ANALYSIS FOR AIRCRAFT TESTING

**M. Tummala, Associate Professor
Department of Electrical and Computer Engineering
Sponsor and Funding: SY84, Aircraft Division,
Naval Air Warfare Center,
Patuxent River, MD**

OBJECTIVE: Develop signal processing algorithms for the analysis of electromagnetic pulse (EMP) waveforms measured in aircraft testing and synthesis of the measured waveforms to produce composite test signals for determining aircraft margin of survivability. This is a three-year project; the work reported here consists of the results obtained during the second year of this effort.

SUMMARY: The Naval Air Warfare Center (Code SY84) conducts EMP testing of aircraft. In order to improve their EMP testing techniques, a method for "bounding" the stress waveforms measured inside the aircraft from a series of tests is sought. At each test-point in an aircraft under test, four to eight stress waveforms (signals received at a test-point in response to a simulated EMP pulse) are measured. These signals are currently sampled at 1.3 GHz with the bandwidth of interest being from about 10 kHz to 100 MHz. Three specific tasks were identified to meet their needs: waveform compression for efficient storage, stress waveform bounding using time series modeling approach, and wideband EMP signal analysis to meet their near future bandwidth requirements (10 kHz to 200 MHz). The first task has been completed during AY1992; the second task has been completed during AY1993, and parts of the third task have been undertaken with the rest to be finished in AY1994.

The autoregressive (AR) modeling approach has been investigated for synthesizing the bounded waveforms. In the first task, the AR models have been successfully used for compressing the EMP waveform data; therefore, we have continued with the AR approach to generate the bounded waveforms as well. We have four stress waveforms per test point, and an AR model has developed for each of those. The poles of the AR models are then combined to synthesize the bounded waveform using two search techniques based on vector quantization and competitive learning neural network algorithms. In the final analysis the bounded waveform produced were highly satisfactory. Nevertheless, the method is prone to yield inconsistent synthesis waveforms when the energy contents of the underlying stress waveforms is significantly disparate. This drawback led us to investigate the feasibility of wideband signal analysis techniques for this work, which is currently in progress.

PUBLICATIONS: Two theses were produced and a report is in preparation.

OTHER: Software developed in Matlab for EMP signal analysis was delivered to Code SY84, NAWC; it has been tested by their personnel on their test database.

DOD KEY TECHNOLOGY AREA: Sensors

KEYWORDS: Data compression, EMP waveform, autoregressive modeling

ELECTRO-OPTICS

HIGH RESOLUTION DIRECT DIGITIZATION AND OPTICAL TELEMETRY OF ANTENNA SIGNALS

P.E. Pace, Assistant Professor

Department of Electrical and Computer Engineering

Sponsor and Funding: Space and Naval Warfare Systems Command

OBJECTIVE: The objective of this research was to investigate the feasibility of directly digitizing, wideband antenna signals using high-resolution techniques to achieve 14-bits resolution.

SUMMARY: An optical interferometer was borrowed from the Optical Sciences Division at NRL to initiate the effort in the NPS optical laboratory. Measurements of the device performance were taken and a 14-bit design based on a new symmetrical number system was developed. Since the interferometer had a V-PI of four volts it was decided that the interferometer was in adequate for 14-bits. After several discussions with NRL and the research team, it was decided to develop a prototype 8-bit design to study the issues that could possibly give problems. Digital hardware consisting of a logic block and an erasable programmable memory was constructed to decode the sampled analog signal into a more familiar binary output. It was also decided to hold discussions with NRL and investigate the possibility of fabricating a new interferometer having a V-PI of 0.2 volts which can instrument the 14-bits.

PUBLICATIONS: The research has produced two conference papers, a presentation, and two journal articles accepted for publication.

DOD KEY TECHNOLOGY AREA: Sensors, Electronic Systems.

KEYWORDS: Symmetrical number system, analog-to-digital conversion, preprocessing, optics.

PASSIVE EVALUATION OF IR TARGETS

R.J. Pieper, Associate Professor

Department of Electrical and Computer Engineering

Sponsor and Funding: Naval Postgraduate School

OBJECTIVE: To investigate, using both experimental measurements and computer modeling, viable schemes for passive characterization of target range and other features based on measurements in the IR bands.

SUMMARY: This project was initiated in Quarter 3 of FY93 and is under continuation into FY94. A method for passive ranging based on the principle of triangulation was investigated. The sensitivity of the range prediction to variation in the bearing accuracy was evaluated in terms of the distance between baselines, target orientation, and range to the target. The dual baseline system

was shown to have significant tactical advantages over a single baseline. Related IRST work which included system modeling and target signature enhancement was also investigated.

PUBLICATIONS: The research produced a master's thesis. A conference paper, presentation, and technical report are forthcoming.

DOD KEY TECHNOLOGY AREA: Sensors.

KEYWORDS: Infrared systems, sensors, polarization effects.

PROPAGATION OF TRANSIENT WAVES

John Powers, Professor

Department of Electrical and Computer Engineering

Sponsor and Funding: Naval Postgraduate School

OBJECTIVE: To study the predicted propagation properties of transient acoustic and optical waves in an effort to understand the propagation of very short duration waves and to use such waves in imaging applications.

SUMMARY: With the ability to generate short-duration sound and light pulses comes the requirement to be able to model and understand the propagation of these waves. Unlike most line-integral techniques presently available, these models should be computationally efficient.

We have developed a method of simulating acoustic propagation in linear homogeneous media based on Fourier transform techniques. The propagation transfer function represents a time-varying spatial filter that increasingly attenuates the higher spatial frequencies of the wave as time increases.

Effort focussed on implementing the model on a large-memory microcomputer using the commercial program, MATLAB, and in using visualization tools to display the calculated four-dimensional wave (three space dimensions and time). Currently, we are constructing a computer-controlled experimental data-collection system to measure experimental acoustic data fields to confirm the technique.

PUBLICATIONS: The research produced a conference presentation, a thesis, a technical report, and a journal article accepted for publication.

DOD KEY TECHNOLOGY AREA: Sensors.

KEYWORDS: Acoustics, wave propagation, transient waves, optics.

ELECTRONIC SYSTEMS

A STUDY OF THE TEMPERATURE HISTORY OF THE PANSAT VEHICLE OVER A SINGLE ORBIT

Allan D. Kraus, Senior Lecturer

Department of Electrical and Computer Engineering

Funding and Sponsor: Naval Postgraduate School

OBJECTIVE: The scientific objective of this research is to use an existing computer code to determine the temperature history of the Pansat vehicle over a single orbit. The extremes of temperature for both the sunlight and shadow zones have been approximated. It is expected that, because of the "thermal time constants," Pansat will never attain these extremes. The actual maximum and minimum temperatures have an impact on the design of the vehicle and must be evaluated before the vehicle design can be made firm.

SUMMARY: The impact of high and low temperatures on the skin of a space vehicle is well known. While the glory of an essentially zero degree Kelvin heat sink is appreciated, the contained equipment "sees" the skin as the heat sink.

PANSAT is an interesting vehicle in that most of its external surface is covered by solar panels and analysis of the steady state performance of the vehicle in both the sunlit and shadow zones have shown that the skin temperatures are somewhat high (in the sunlit zone) and somewhat low (in the shadow zone). These skin temperatures have an impact on the performance of the storage batteries used in conjunction with the solar cells.

However, because the vehicle will not remain in either the sunlit or shadow zone long enough for the extreme temperatures to be reached, there is promise that the equipment will be exposed to more amenable skin temperatures. This, led to the work statement for this research: USE AN EXISTING COMPUTER CODE TO DETERMINE THE SINGLE-ORBIT TEMPERATURE PATTERN FOR THE PANSAT VEHICLE.

PANSAT has been modeled (based on up-to-date Engineering Information) both for steady state and transient thermal analysis. The steady state model has been run in order to determine the effect of any design changes since the last analysis. Weight-specific heat data has been incorporated into the steady state model in order to conduct the transient analysis. An iterative transient analysis has been performed with the analysis cutoff determined at the point where the temperatures at entrance at both the sunlight and shadow zones do not differ by more than 0.1 deg F for three successive passes.

DOD KEY TECHNOLOGY AREAS: Environmental Effects, Software.

KEYWORDS: Space vehicle, orbital effects, sunlit and shadow zones, computer aided design and analysis.

**THE FEASIBILITY OF A THERMOELECTRIC COOLER FOR
E-2C ENVIRONMENTAL CONTROL**

**Allan D. Kraus, Senior Lecturer
Department of Electrical and Computer Engineering
Sponsor and Funding: NAS PAX River**

OBJECTIVE: Determine the feasibility of using a thermoelectric air conditioner in the EC-2 aircraft. The ultimate objective is to minimize the impact of the discontinued use of Freon as a refrigerant in vapor compression air conditioning and refrigeration systems.

SUMMARY: Exhaustive calculations have been performed to determine the feasibility of the employment of a thermoelectric air conditioner to replace the freon air conditioner (environmental control system) presently employed on the E-2C aircraft.

PUBLICATION: A thesis was produced.

DOD KEY TECHNOLOGY AREA: Environmental Devices.

KEYWORDS: Thermoelectric, Bismuth-Telluride semiconductor, vapor compression, refrigeration, air conditioner.

**ADVANCED ANALOG VLSI DESIGN FOR IC's AND
NEURAL NETWORKS IMPLEMENTATIONS**

**Sherif Michael, Associate Professor
Department of Electrical and Computer Engineering
Sponsor and Funding: Naval Postgraduate School**

OBJECTIVE: To design and implement an advanced Stray insensitive Switched-Capacitor, Analog VLSI as a building block for future Neural networks

SUMMARY: Development of high performance, low sensitivity analog VLSI is proposed in this research. A novel technique for designing advanced active building blocks essential for VLSI implementation is investigated. The new designs are based on the Composite Amplifiers, previously introduced by the investigator. The research goal is to develop Stray-Insensitive Switched-Capacitor analog building blocks that will be used in the follow-up project to design and build a high performance analog VLSI circuits. The availability of such novel designs would play a key role in the practical implementations of Neural Networks.

PUBLICATIONS: The research produced two conference proceedings, two conference presentations, and four theses.

DOD KEY TECHNOLOGY AREA: Electronic Devices.

KEYWORDS: Analog VLSI, low sensitivity, switched-capacitors, neural networks application.

POWER SYSTEMS

AN ADAPTIVE ESTIMATION TECHNIQUE FOR CONTROLLING ACTIVE POWER LINE CONDITIONERS

Robert W. Ashton, Assistant Professor

Department of Electrical and Computer Engineering

Sponsor and Funding: NPS -- Research Initiative Program

OBJECTIVE: The implementation of a computer controlled system which at least in part actively compensates for harmonics in a power system with only the knowledge of the bus voltage.

SUMMARY: Due to the proliferation of power electronics devices in recent years, the amount of harmonic current injected into the power system is on the increase causing undesirable voltage waveform distortion. This distortion can cause additional losses in switchgear, rotating machines and transformers. Induction machines may vibrate due to parasitic torques or not develop sufficient starting torque. Capacitors will age faster due to excessive dielectric losses and stress. The goal of this research is to implement a system which can at least in part cancel harmonic currents in a power system with only the knowledge of the distorted bus voltage. The power system characteristics are established through an adaptive estimation technique which feeds and Active Power Line Conditioner with the proper control information through an iterative process. The adaptive estimation system could also be used to supply power to a number of dc loads while at the same time compensating harmonics on a source ac bus. The whole system is controlled using a personal computer making it flexible to the needs of a particular power system.

PUBLICATIONS: The research produced one conference paper and one MS thesis.

DOD KEY TECHNOLOGY AREA: Other.

KEYWORDS: Line conditioners, harmonics, adaptive estimation, active filters.

ON-ORBIT ANNEALING OF SATELLITE SOLAR PANELS

Sherif Michael, Associate Professor

Department of Electrical and Computer Engineering

Sponsor and Funding: SPAWAR, Space and Naval Warfare Command

OBJECTIVE: Investigate the possibility of on-orbit annealing of satellite's InP and GaAs Solar Cells using the new Minority Carriers Annealing Techniques.

SUMMARY: This is a continuation of the ongoing research on Photovoltaic Power Technology. Research tasks include the development and completion of the Solar and Radiation Laboratory, the development of the microprocessor based

Photovoltaic experiment as well as testing of the solar panels for the PANSAT satellites. The tasks also include investigation of Photovoltaic current annealing processes and other topics of electron and proton radiation effects on GaAs, InP and Si devices.

PUBLICATIONS: The research produced two conference proceedings, a conference presentation, and a thesis.

DOD KEY TECHNOLOGY AREA: Electronic Devices, Environmental Effects, Energy Conversion.

KEYWORDS: Space radiation effects, satellites, annealing, radiation hardening

UNINTERRUPTABLE POWER SUPPLY DESIGN
FOR COMMUNICATION SYSTEM

Sherif Michael, Associate Professor
Department of Electrical and Computer Engineering
Sponsor and Funding: Marine Corps System Command (DFMQ)
Quantico, VA

OBJECTIVE: To develop and design an Uninterruptable power supply for the MRK-142 on board Marine EBMV.

SUMMARY: This research is proposed to Design and Develop a prototype Uninterruptable Power Supply. The result would be an improved Power Distribution Panel that will provide the capability to manually switch between two AC sources, to the EBMV DC battery/alternator or other DC sources. This would be accomplished with no interruption in the AN/MRC-142 communication system operation.

PUBLICATIONS: The research produced a presentation and a thesis.

DOD KEY TECHNOLOGY AREA: Electronic Devices, Energy Conversion.

KEYWORDS: Uninterruptable power supply, reliable communication system.

HYBRID POWER SYSTEM FOR REMOTE COMMUNICATION STATIONS

Sherif Michael, Associate Professor
Department of Electrical and Computer Engineering
Sponsor and Funding: U.S. Coast Guard,
Coast Guard Island, Alameda

OBJECTIVE: Developing a Photovoltaic/Windturbine Hybrid Power System to provide electrical power to the Coast Guard Communication Stations in different Alaska remote sites.

SUMMARY: This research is proposed to investigate the possibility of

incorporating different power systems to provide electrical power to Alaska's Coastal Voice Distress Network, operated by the U.S. Coast Guard. Research tasks include investigating the performance of Thermo-Electric Generators (TEG) providing power to the current systems. Investigating present and new power sources technologies. Investigating different energy resources available at the proposed stations sites, including seasonal changes studies. Developing and designing reliable hybrid power systems capable of utilizing available

energy sources at these sites. These systems would probably incorporate wind power, solar power and TEG systems.

PUBLICATION: A master's thesis was produced.

DOD KEY TECHNOLOGY AREA: Energy Storage, Environmental Effects, Energy Conversion.

KEYWORDS: Solar cells, wind power, hybrid power system.

RADAR AND ELECTRONIC WARFARE

ULTRA WIDEBAND RADAR WAVEFORMS AND SIGNAL PROCESSING

G.S. Gill, Visiting Associate Professor

Department of Electrical and Computer Engineering

Sponsor and Funding: Office of Naval Research

OBJECTIVE: The goal of this project is to investigate waveforms for Ultra Wideband (UWB) radars and to identify suitable signal processing techniques. The study of wideband radar signals will also be included in this ongoing project.

SUMMARY: Initially, the generation of two different types of UWB waveforms was undertaken in this project. In the impulse waveform area an assessment was made of the technology which is being developed for high power microwave sources. Generation of high power impulses requires energy compression, that is, mechanisms to store and to release the energy. The technology of both aspects was examined.

The generation of a second waveform based on Fourier synthesis was also examined. Fourier based waveforms have several advantages over impulse waveforms such as accurate control of pulse shapes, pulse repetition interval, and the spectrum. This method was extended to the generation of binary coded waveforms. The generation of such codes is important as it allows for the use of longer pulses. These coded pulses contain more energy and improve the signal to noise ratio while still retaining the range resolution and other benefits of smaller pulse widths. Also, ambiguity function techniques were employed to investigate the UWB waveforms including the ones proposed and developed in this study.

PUBLICATIONS: Three master's theses have been produced and two conference

papers have been accepted for publication.

DOD KEY TECHNOLOGY AREA: Sensors.

KEYWORDS: UWB, waveforms, signal processing.

RADAR CROSS SECTION AND SCATTERING STUDIES

David C. Jenn, Associate Professor
Department of Electrical and Computer Engineering
Sponsor and Funding: Naval Postgraduate School

OBJECTIVE: The goal of this research was to further enhance the capabilities of a set of radar cross section (RCS) and radome analysis computer codes. The codes were originally developed during an earlier phase of this project, and have been delivered to several Navy labs (NRaD and the Naval Air Warfare Center in China Lake) as well as private contractors.

RCS analysis has been applied to axially symmetric reflector antennas, including their feeds. The code uses the method of moments to accurately model the interactions between the reflector surfaces and feed. A second code uses a method of moments solution to evaluate the defocusing and depolarization effects of curved radomes on microwave scanning antennas. This type of radome is frequently used in fighter aircraft and missile applications, and its presence can adversely affect the radar's performance. This solution is unique in that it allows the radome to be in the near field of the antenna. This situation is commonly encountered in practice, and cannot be handled by the usual radome models.

Verification and testing of the computer codes have been completed. Verification consisted of comparing computed data with previously published measured and calculated data. Measurements were performed on a AGM-86 HARM radome in the NPS anechoic chamber, and good agreement was obtained between the two.

Enhancements included revising several of the code subroutines to allow a broader range of antenna amplitude and phase excitations. With these changes, low sidelobe and shaped beam antennas can be simulated.

PUBLICATIONS: One journal article, three conference papers, and two theses have been produced.

DOD KEY TECHNOLOGY AREA: Sensors.

KEYWORDS: Radomes, radar cross section, antennas.

**EM SCATTERING FROM A TUBULAR CYLINDER OF
ANISOTROPIC SURFACE IMPEDANCES**

**H.-M. LEE, Associate Professor
Department of Electrical and Computer Engineering
Sponsor and Funding: Sandia National Laboratories**

OBJECTIVE: To investigate the effects of impedance coating on the scattering of electromagnetic waves by a body in the resonant region. To develop accurate computer codes as a reference standard.

SUMMARY: The electromagnetic scattering from a zero-thickness, perfectly conducting, circular, tubular cylinder of finite length with different anisotropic coatings on its inside and outside surfaces is investigated. The induced electric and magnetic surface current densities and the far field are obtained. Analytical expressions of the double series expansion coefficients of the kernels of the integral-differential equations of this problem are found and utilized in the computation to assure that extremely accurate numerical results can be obtained. These results will be used as a standard for validating numerical electromagnetic computation codes.

PUBLICATIONS: The research produced two conference papers and an article in preparation.

DOD KEY TECHNOLOGY AREAS: Software, Sensors.

KEYWORDS: Radar cross section, impedance coating, anisotropic material, stealth.

**AIRBORNE COUNTERMEASURES AGAINST THE
LASER GUIDED SURFACE-TO-AIR MISSILE THREAT**

**Frederic H. Levien, Senior Lecturer
Department of Electrical and Computer Engineering
Sponsor and Funding: Naval Air Systems Command**

OBJECTIVE: Investigate airborne countermeasures capable of defeating the laser guided surface-to-air missile threat by defining first, the parameters of a postulated LSAM threat and engagement scenario, then identify flight scenario constraints, and design criteria for

countermeasures, and finally look at current developmental alternatives, and choosing the best counter LSAM threat design.

SUMMARY: Two alternatives were identified as being mature enough to meet required real world constraints and operational performance criteria. A plan for further development and flight testing was recommended so as to verify and expand preliminary results.

PUBLICATION: A master's thesis was produced.

DOD KEY TECHNOLOGY AREAS: Sensors, Electronic Devices.

KEYWORDS: Lasers, missiles, EW, countermeasures.

**AIRBORNE COUNTERMEASURES TO ADVANCED
LASER BEAMRIDER SURFACE-TO-AIR MISSILES**

**Frederic H. Levien, Senior Lecturer
Department of Electrical and Computer Engineering
Sponsor and Funding: Naval Air Systems Command**

OBJECTIVE: Investigate, analyze, compare, and assess the effectiveness and feasibility of potential countermeasures to laser beamrider surface-to-air missiles.

SUMMARY: Laser-aided weapons are known to be widely manufactured and deployed by military organizations world wide. Of these systems, laser beam riders pose one of the most advanced and potentially lethal threats faced by aircraft today. This research developed a proposal and defined the optimal solutions to protect air crews from this threat. Two concepts were identified as most promising, and their parameters presented.

PUBLICATION: A master's thesis was produced.

DOD KEY TECHNOLOGY AREAS: Sensors, Electronic Devices.

KEYWORDS: Lasers, missiles, EW, countermeasures.

**AUGMENTATION OF THE IMPROVED MANY-ON-MANY (IMOM)
JAMMER EFFECTIVENESS MODEL**

**Frederic H. Levien, Senior Lecturer
Department of Electrical and Computer Engineering
Sponsor and Funding: Air Force Electronic Warfare Center**

OBJECTIVE: This research was initiated to upgrade the Air Force Primary Modelling and Simulation Electronic Warfare Mission Planning System, IMOM, to include the jamming algorithm for the EA-6B, allowing the system to now be used jointly by Navy as well as Air Force mission planners.

SUMMARY: The specific programming enhancements provided to upgrade IMOM included a program change to AUTOJAM, written in ADA, and another providing analysis of jammer transmitters and modulations utilized by Navy/Marine Corps Prowler EA-6B aircraft. These enhancements allow for automation of jammer planning and extension of the range of jammer choices in IMOM.

PUBLICATION: A master's thesis was produced.

DOD KEY TECHNOLOGY AREAS: Computers, Software, Human Systems Interface.

KEYWORDS: EW, radar, modelling, simulation.

**TRANSPORTABILITY ISSUES OF UNINTENTIONAL
MODULATION-ON-PULSE EMITTER DATA
AMONG NAVY ESM PROCESSORS**

**Frederic H. Levien, Senior Lecturer
Department of Electrical and Computer Engineering
Sponsor: Naval Research Laboratory
Funding: Naval Postgraduate School**

OBJECTIVE: To determine the feasibility of transporting unintentional Modulation-on-Pulse data that has been compiled by an NRL system utilizing the UYX-2 processor and the

Grumman Aircraft Corporation AFX/P processor, to the systems planned for operational employment in the EA-6B ADVCAP aircraft.

SUMMARY: This study determined the process by which both UMOP processors functioned, and compared the resultant data from the same source, as recorded by each processor. It then examined the feasibility of choosing either or both as a source of library inputs to an EA-6B application.

PUBLICATION: A master's thesis was produced.

DOD KEY TECHNOLOGY AREAS: Computers, Software, Design Automation, Radar.

KEYWORDS: EW, radar, UMOP, transportability, EA-6B.

**OPERATION OF AND POTENTIAL COUNTERMEASURES AGAINST
MISSILE SYSTEMS USING VISUAL IMAGING SEEKERS**

**Frederic H. Levien, Senior Lecturer
Department of Electrical and Computer Engineering
Sponsor and Funding: Naval Air Systems Command**

OBJECTIVE: To analyze the general operation of current and emerging missile systems using the visible spectrum and to evaluate proposed countermeasures that could be used to degrade missile effectiveness.

SUMMARY: The introduction of missile systems using visual imaging seekers has added a significant surface-to-air and air-to-air missile threat to all types of aircraft. This research evaluates seeker operation by focusing on target acquisition and tracking in the visible spectrum. Key technologies as well as the tracking algorithm are surveyed to establish the vulnerabilities and weaknesses of these systems.

PUBLICATION: A master's thesis was produced.

DOD KEY TECHNOLOGY AREAS: Computers, Sensors, Human System Interface.

KEYWORDS: Visual imaging, EW, missiles, countermeasures.

**ALGORITHMS FOR ASSESSING THE EFFECTIVENESS OF SHIPBOARD
COUNTERMEASURES AGAINST ANTI-SHIPPING MISSILE PLATFORMS**

P.E. Pace, Assistant Professor

Department of Electrical and Computer Engineering

Sponsor and Funding: Tactical Electronic Warfare Division

Naval Research Laboratory

OBJECTIVE: The objective of this research is to improve the process for evaluating hardware-in-the-loop and field test performance results. As part of this objective, new algorithms to measure the overall EW systems utility and effectiveness were to be developed.

SUMMARY: Hardware-in-the loop data from NRL's Central Targeting Simulator facility was obtained. This data demonstrates the response of various anti-shiping missile platforms (open loop/closed loop) in an electronic countermeasures environment. Simulation models of various missiles were constructed to incorporate this data to measure the effectiveness of the various ECM waveforms. After discussion with the Integrated EW Simulation Scientists, it was determined that incorporation of the true seeker response could add additional confidence in the simulation results. It was decided to obtain characterization data corresponding to the seeker currently under study. Incorporation of this type of analysis into the simulation models (reverse engineering) is expected to further increase the accuracy of the performance predictions.

PUBLICATION: A conference paper was produced.

DOD KEY TECHNOLOGY AREA: Sensors.

KEYWORDS: Anti-shiping missiles, electronic countermeasures, simulation.

**SURFACE MODE PROCESSING FOR TARGET DETECTION
AND DECLARATION**

P.E. Pace, Assistant Professor

Department of Electrical and Computer Engineering

Sponsor and Funding: Hughes Missile Systems Company

OBJECTIVE: The objective of this research was to experimentally evaluate the trade-offs between an inverse MTI filtering approach and a DFT filter bank approach to detect surface targets in sea clutter.

SUMMARY: Trade-offs in performance versus hardware complexity were evaluated for two search processor configurations for several slow moving targets of various

size buried in recorded sea clutter data. Several variations were investigated for each approach. A retrofit of the current Phalanx hardware to perform this search/detection processing was studied and an optimal inverse filter was constructed that could easily be implemented in the currently configured hardware. Overflow effects and truncation noise levels were numerically evaluated.

PUBLICATIONS: The research produced a journal article accepted for publication, a technical report, a conference paper, and two master's theses.

DOD KEY TECHNOLOGY AREA: Sensors.

KEYWORDS: Phalanx, close-in-weapon-system, surface mode signal processing, sea clutter.

MISSILE SIMULATION

H. Titus, Professor

Department of Electrical and Computer Engineering

Sponsor and Funding: U.S. Army Missile and
Space Intelligence Center

OBJECTIVE: The purpose of this effort was to support the Crossbow Committee and several of their intelligence teams. We studied and simulated several Soviet missiles and attempted to develop techniques to counter them.

SUMMARY: We have studied and simulated in considerable detail, the Soviet SA-6, SA-11, and now the follow on system, SA-17x. The SA-6 was used effectively in the 73 War by Egypt. The follow on, the SA-11 is operational in the Soviet Union. The SA-17x is in R&D test. Our task was to know everything possible about the guidance and control of these systems. We have had frequent briefings by CIA, NSA, DIA, MSIC, and others. The simulations have been used to study the missile systems and how to counter them. The purpose of this group is to design and develop several of these systems to be used at appropriate Air Force and Navy facilities. This past year we have also been studying the SA-15, which is a follow on to the SA-8. However, it is totally new in many aspects; featuring multi-target tracking capability (48 targets) and vertical launch missiles with new ECCM and new EO systems. Export versions of this system are now on sale. In country versions have some significant added capabilities which we are attempting to determine. Numerous meetings and discussions were held. A workshop on missile guidance was given at Huntsville, Alabama. LT Painter's thesis involved a SA-11 Missile Target Simulation. LT Tim Mull developed a simulation and design for the vertical launch phase of these missiles. He did this for the SA-15 and the Sea Sparrow. Work is continuing reviewing threat simulator validation reports.

DOD KEY TECHNOLOGY AREA: Software.

KEYWORDS: Tracking, missiles, simulation.

SIGNAL PROCESSING

INVESTIGATION OF SPECTRAL-BASED TECHNIQUES FOR CLASSIFICATION OF WIDEBAND TRANSIENT SIGNALS

Monique P. Fargues, Assistant Professor

Ralph Hippenstiel, Associate Professor

Department of Electrical and Computer Engineering

Sponsor and Funding: US Army Communications Center for
Signal Warfare

OBJECTIVE: The goal of this project is to investigate and to implement, using Fortran, a fast and reliable way to classify wideband transient signals provided by the sponsoring organization.

SUMMARY: This study investigates two spectral-based procedures to efficiently classify certain classes of transient signals. Both schemes use a selected number of spectral coefficients for the classification procedure. The first approach considered uses spectral-based measures to distinguish between classes of transients. Four different measures are studied: the normalized cross-correlation coefficient, the Bhattacharyya distance, the divergence (related to the Kullback-Liebler number), and the modified normalized cross-correlation coefficient. Results show that the four measures can be used to classify the transients in different classes. They also indicate that a better performance is obtained when using the normalized cross-correlation measure (MNCC). Furthermore, the MNCC has a natural interpretation which allows for a simple interpretation by a human operator.

The second approach considered uses a back-propagation neural network (NN) approach. The NN is trained to distinguish between the different classes of signals provided by the sponsor. Results show that the NN can be successfully trained to distinguish between the three different classes. Results are found to be consistent with those obtained using the spectral-based approach. The main drawback behind the NN approach is that it requires a large number of data to be trained with enough reliability.

PUBLICATIONS: One technical report and one conference paper have been produced.

DOD KEY TECHNOLOGY AREA: Electronic Devices.

KEYWORDS: Transient detection/classification, spectral distance measure, neural network application.

TRACKING SOURCES USING THE RANK-REVEALING OR FACTORIZATION

Monique P. Fargues, Assistant Professor

Department of Electrical and Computer Engineering

Funding: None

OBJECTIVE: The goal of this continuing project is to investigate the application

of the Rank-Revealing QR (RRQR) factorization to compute the signal information, and to take advantage of the simplicity of the QR update to track moving sources.

SUMMARY: Subspace decomposition methods are a powerful tool used in different areas of Signal Processing in which the signal information is usually obtained via eigen-based or SVD-based methods. These techniques are numerically very stable but expensive to update. The RRQR factorization provides an attractive alternative to accomplish subspace selection. We have refined the original algorithm proposed earlier, and have added an updating capability to the RRQR factorization. We have applied the resulting procedure to the Direction Of Arrival (DOA) problem. Simulations show the performance of the "refined" adaptive RRQR-based technique is similar to that obtained using classical eigen-based techniques.

PUBLICATIONS: The research produced a conference paper and a journal paper in preparation.

DOD KEY TECHNOLOGY AREA: Electronic Devices.

KEYWORDS: DOA problem, tracking, QR factorization.

ANALYSIS USING BI-SPECTRAL RELATED TECHNIQUES

R. Hippenstiel, Associate Professor
Department of Electrical and Computer Engineering
Sponsor and Funding: Naval Command Control Ocean
Surveillance Center

OBJECTIVE: The goal of this project is to investigate the performance of a Bi-spectral related technique in detecting stationary and non-stationary spectral components.

SUMMARY: Earlier results indicate that a 1½-D spectral technique (a degenerate version of the Bi-spectrum) has potential Signal to Noise Ratio (SNR) gain over conventional techniques. This is partially due to the cumulant's response to Gaussian noise, which theoretically is zero. Using synthetic data and real ocean acoustic data the performance of the 1½-D technique is shown in comparison with a conventional spectrogram and an instantaneous power spectrum. The results of the simulation (synthetic data) are supported by theoretical performance bounds.

PUBLICATIONS: A technical report and a master's thesis were produced.

DOD KEY TECHNOLOGY AREA: Electronic Devices.

KEYWORDS: Signal detection/classification, bi-spectrum, cumulants, instantaneous power spectrum.

WAVELETS TIME-FREQUENCY ANALYSIS OF SIGNALS AND SYSTEMS

Alex W. Lam, Associate Professor
Department of Electrical and Computer Engineering
Sponsor and Funding: Naval Research Laboratory

OBJECTIVE: The goal of this project was to investigate wavelets and time-frequency analysis of signals and systems.

SUMMARY: We investigated wavelet-based time-frequency analytical techniques for transient signals and digitally modulated signals. Problems of particular interest were the detection and classification of multiple damped sinusoidal signals and chirped waveform in additive noise. The time-frequency decompositions of BPSK and QPSK signals, as well as spread-spectrum signals were obtained using a multi-resolutional approach.

PUBLICATION: A technical report is forthcoming.

DOD KEY TECHNOLOGY AREA: Communications Networking.

KEYWORDS: Wavelets, time-frequency analysis, digital modulations, spread-spectrum.

ADVANCED SIGNAL PROCESSING TECHNIQUES

H.H. Loomis, Jr., Professor
M. Soderstrand (Visiting) and R. Bernstein
Department of Electrical and Computer Engineering
Sponsor and Funding: Secretary of the Air Force

OBJECTIVE: To investigate advanced signal processing algorithms and architectures for the detection and characterization of broadband communications signals in noise and interference.

SUMMARY: My principal accomplishment this year has been in the development, realization, and experimental verification of algorithms for the detection and characterization of cyclostationary signals, such as Phase Shift Keyed (PSK) signals. This work has resulted in one Journal article, three conference papers three presentations and one thesis. Cooperative work with M. A. Soderstrand of UC Davis has resulted in continuing progress in the area of adaptive interference removal.

PUBLICATIONS: The research produced two journal articles, three conference papers, three presentations, and a master's thesis.

DOD KEY TECHNOLOGY AREA: Sensors.

KEYWORDS: Signal detection, source location, cyclostationarity, high speed computing.

LORAN-C TRANSMITTER MODELING AND PULSE SHAPING

M. Tummala, Associate Professor

Department of Electrical and Computer Engineering

Sponsor and Funding: Electronics Engineering Center

U.S. Coast Guard, Wildwood, NJ

OBJECTIVE: The goal of this project was to develop signal processing algorithms for modeling of Loran-C transmitters and online shaping of the Loran-C output waveform to meet Coast Guard's specifications. This was a two-year project; the work reported here consists of the concluding part of the two-year effort.

SUMMARY: The Loran-C transmitter is a non-linear and time varying device. We have developed pole-zero models for these transmitters taking the time variations and nonlinearities (as measured from actual experiments) into account. We have used a set of concatenated models to accommodate the nonlinearities and the time variations are tracked using adaptive parameter estimation algorithms. The AN/FPN-42 required 4 poles and 3 zeros while AN/FPN-44A required 6 poles and 3 zeros. In both cases, the waveforms generated by models agreed with the actual transmitter output waveforms under a variety of operating conditions.

The manual methods to control the Loran-C output waveshape is currently used by the Coast Guard, and the Electronics Engineering Center plans to replace the manual control by computer algorithms to achieve better waveshape control and reduced hardware maintenance. We have developed two approaches to accomplish this: a gradient based algorithm and a multichannel parametric algorithm. The multichannel algorithm has yielded more promising results than the gradient algorithm under a variety of simulated noisy operating conditions. The personnel at the Electronics Engineering Center are now proceeding with the work to test these algorithms on actual transmitters.

PUBLICATIONS: The research produced three conference papers and one master's thesis.

DOD KEY TECHNOLOGY AREA: Sensors.

KEYWORDS: Pole-zero modeling, waveshape control, Loran-C transmitter.

SYSTEMS AND CONTROL

AUTOMATIC CONTROL OF AN EXTREMELY HIGH FREQUENCY ANTENNA

Roberto Cristi, Associate Professor

Department of Electrical and Computer Engineering

Sponsor and Funding: NISE West (formerly NAVELEX), Vallejo, CA

OBJECTIVE: This project aims at the design of a control system for rapid pointing of an antenna for EHF satellite communication. Primary objective is the estimation of offsets due to installation and construction tolerances, which affect the extremely tight pointing tolerance of two degrees. This is the second year of the project, began in FY 1992.

SUMMARY: The Navy Extremely High Frequency (EHF) antenna program utilizes a three axis antenna possibly mounted on a ship. Due to the very short wavelength involved, the positioning accuracy is very restrictive. In an effort to alleviate errors induced by machine and installation tolerances, very lengthy procedures are currently involved to properly align the antenna axis. An alternative way proposed in this research is to model the installation errors, and estimate the parameters from data collected on the control system during satellite tracking. To this goal the use of Euler's parameters has shown to be a very effective tool, and a complete mathematical model has been derived. The parameters are estimated by robust least squares techniques on the basis of measurements from the inertial navigation of the ship (heading, pitch, and roll), the ephemeris of the satellite tracked and the commands given to the antenna's syncros. Data collected from the ship cruising at different headings provide sufficient information to insure that the technique is well conditioned and least sensitive to measurement errors. The research has resulted in a technical report.

DOD KEY TECHNOLOGY AREA: Communications Networking.

KEYWORDS: Communications, control, estimation.

TORPEDO TRACKING

H. Titus, Professor

Department of Electrical and Computer Engineering

Sponsor and Funding: NUWES, Keyport, Washington

OBJECTIVE: Our task was to develop a Kalman filter torpedo tracking program which incorporated the acoustic range data and the torpedo's INS data as well.

SUMMARY: For over a dozen years, we have had thesis students and faculty involved in various torpedo tracking problems as requested by the research arm of the NUWES facility. This past year we investigated the Kalman filter fusing and smoothing of the range acoustic data with an internal INS data. LT Alfaro has done a very good job and they are incorporating his work. The problem was made interesting due to the fact that the INS had very high drift rates, making

a problem in aligning accelerometer outputs to the range coordinate system. The observation rates were non-synchronous, and the acoustic data had dropouts, and discontinuities as the torpedo would pass from one acoustic array to another. LT Wiseman is following on with LT Alfaro's work, incorporating a new maneuver detection algorithm, and now utilizing the accelerometers. The work is classified. Presentations were given at NUWES. LT Turpening continued on with LT Wiseman's work. Professor Art Schoenstadt and Professor Titus are continuing with some software updates. The project was completed in the fall of 1993.

DOD KEY TECHNOLOGY AREA: Software.

KEYWORDS: Tracking, torpedo, simulation.

SPACE RESEARCH

H. Titus, Professor

Department of Electrical and Computer Engineering

Sponsor and Funding: SPAWAR, NRL, Washington, DC

OBJECTIVE: We wish to locate targets from space platforms and to develop optimal control techniques for attitude control and maneuver of spacecraft.

SUMMARY: Algorithms have been developed to FFT process high PRF pulse Doppler signals and then Kalman filter observable parameters from these coefficients to locate targets of interest. We are presently waiting to test the algorithms on real data. Simulations have been performed on representative signals. Optimal control techniques have been applied in the general attitude control and spacecraft maneuver problem. LTs Mika and Uner did theses on "Fast Envelope Correlation for Passive Ranging" and "Frequency, Amplitude, and Phase Tracking of Non-Sinusoidal Signal in Noise With Extended Kalman Filter," respectively. Cooper's thesis involved a third order optimal control for spacecraft attitude control. Research briefings were given at NRL. A paper, "Second and Third Order Minimum Time Controllers and Missile Adjoints," was presented by Cooper and Titus at the 34th Midwest Symposium on Circuits and Systems, Monterey, CA, May 14--17, 1991. LTs Mika and Haefner have worked on the analysis of radar emitter signatures via FFT and time domain filtering. LT Sipe continued this effort. LT Merx addressed the problem of placing the sensor on a specific platform and its control problems. Capt Williamson and LT Fallon are extending this work to include RPVs and other sensor platforms. Sensor fusion for locating threat missile and missile radar are being addressed.

DOD KEY TECHNOLOGY AREA: Software

KEYWORDS: Tracking, missiles, simulation

UNDERWATER ACOUSTICS

BASIC RESEARCH INTO WAVELETS AND THEIR APPLICATION TO UNDERWATER SURVEILLANCE PROBLEMS

Monique P. Fargues, Assistant Professor

Ralph Hippenstiel, Associate Professor

Department of Electrical and Computer Engineering

Sponsor: NCCOSC, San Diego, CA

Funding: Naval Postgraduate School

OBJECTIVE: The goal of this continuing project is to investigate the properties of wavelets as they relate to underwater surveillance detection and identification problems.

SUMMARY: The study of the spectrum of signals, usually imbedded in additive noise, is important in SONAR/RADAR target detection and target identification. Time-Frequency (TF) transformations have been used to track time-varying signal variations. However, abrupt changes in the signal behavior cannot be simultaneously analyzed using TF transforms with long duration windows required for good frequency resolution and short duration windows required for good temporal resolution. A good compromise can be obtained with the Wavelet transform (WT) which is better able to track abrupt changes in signal behavior.

Four main implementations of the Wavelet transform have been considered. The "Discrete" continuous Wavelet transform, and three recursive discrete implementations of the WT. The discrete implementations considered were the decimated and undecimated A-Trous algorithm, and the Mallat algorithm. The Morlet wavelet was used for the A-Trous implementations.

Various synthetic signals have been examined using the different WT representations. In addition, the WT and TF implementations have been applied to detect real-world Ultra-wideband (UWB) transient signals in non-stationary sea clutter and RFI interference. The UWB data was provided by the Radar Branch of NCCOSC, San Diego, CA. Results show that better performance is obtained using the A-Trous WT algorithm to detect the transient signals accurately while other TF representations, except for the Instantaneous Power Spectrum, were not able to detect the transients. Results also show that the choice of the number of voices, the center frequency and the rolloff coefficient of the Morlet wavelet may be used to enhance detection of the transients considered in the study.

PUBLICATIONS: One conference paper published, two conference papers presented, and one MS thesis was produced. Wavelet Transform software designed to detect UWB transient in the presence of non stationary noise and RFI interference was provided to the Radar Branch of NCCOSC, San Diego, CA, Dec 1992.

DOD KEY TECHNOLOGY AREA: Electronic Devices.

KEYWORDS: Transient detection, wavelet transform, ultra-wideband radar.

MODELING, DETECTION, AND RECOGNITION TECHNIQUES
FOR UNDERWATER BIOLOGICAL DATA

Monique P. Fargues, Assistant Professor

Roberto Cristi, Associate Professor

Department of Electrical and Computer Engineering

Funding: None

OBJECTIVE: The goal of this continuing project is to investigate the applications of reduced-rank Autoregressive (AR) and Autoregressive-Moving Average (ARMA) modeling techniques to identification of biological underwater sounds.

SUMMARY: The first part of the research investigated the application of reduced rank AR modeling to the identification and classification of various underwater biological sounds. Two classification methods were considered. The first method considered investigated the use of backpropagation neural networks and reduced-rank AR models to identify biological sounds (such as humpback whale or killer whale sounds, for example). The second method investigated the use of spectral distances (such as the Symmetrized Itakura distance) for biological sound classification. The digitized acoustic data used for the research was obtained from audio tapes provided by the Hopkins Marine Station of Stanford University, Pacific Grove, CA. Results show that reduced-rank AR models can be used successfully for biological sound classification both with the neural network configuration and the spectral distance approach. They also show that the spectral distance method is more restrictive as it requires a consistent set of sounds to be used successfully within a given species.

PUBLICATIONS: One conference paper and one MS thesis were produced.

DOD KEY TECHNOLOGY AREA: Electronic Devices.

KEYWORDS: Modeling, underwater signal classification, spectral measures.

TIME DOMAIN LOCALIZATION

J.H. Miller, Associate Professor

Department of Electrical and Computer Engineering

C.-S. Chiu, Associate Professor

Department of Oceanography

Sponsor and Funding: NUWC New London

OBJECTIVE: The goal of this work is the determination of source range and depth in an ocean acoustic waveguide given a time domain representation of a source-generated signal. This is the second year of the project.

SUMMARY: In this reporting period, algorithms were developed for the passive localization of transients generated by a submarine. These algorithms are tested with actual data acquired by a submarine spherical array. The algorithms rely on the exploitation of knowledge of the transfer function of the shallow ocean

waveguide between the emitting submarine and the receiving submarine. One algorithm, autocorrelation matching, performs adequately in localizing transients at three different ranges from 1800 to 3850 m.

PUBLICATIONS: The research produced one journal article, one technical report, one conference paper, and three MS theses.

DOD KEY TECHNOLOGY AREA: Sensors.

KEYWORDS: Transient, localization, submarine.

SONAR SIGNAL MODELING

Charles W. Therrien, Professor
Department of Electrical and Computer Engineering
Sponsor and Funding: Naval Undersea Warfare Center
New London

OBJECTIVE: This research involves the development of models for underwater signals received by a passive sonar to support work in classification.

SUMMARY: Research on modeling of acoustic transients and related sonar data was carried out in fiscal year continued in 1993. A comprehensive study to compare ARMA modeling to three other analysis/synthesis methods used in speech modeling was carried out. New work on ocean noise modeling was carried out and a new filtering method for noise removal was developed. Finally, some new methods for data synthesis were developed. Data generated by these methods matches recorded acoustic data in the time and frequency domain. In aural evaluation the data is virtually indistinguishable from physically generated and recorded sonar data.

PUBLICATIONS: The research produced one journal article, two technical reports, one conference paper, two MS theses, and one journal article to appear.

DOD KEY TECHNOLOGY AREA: Sensors.

KEYWORDS: Passive sonar, ARMA modeling, signal modeling, acoustic transients.

RECURSIVE RAY ACOUSTICS FOR THREE-DIMENSIONAL SPEEDS OF SOUND

Lawrence J. Ziomek, Associate Professor
Department of Electrical and Computer Engineering
Sponsor: Naval Sea Systems Command (NAVSEA)
Funding: NAVSEA

OBJECTIVE: Continue to generalize, test, and evaluate the Recursive Ray Acoustics (RRA) Algorithm. The RRA Algorithm is a simple, fast, and accurate algorithm that can be used to compute the position, angles of propagation, travel time, and path length along a ray path and to draw ray trace plots for speeds of

sound that are functions of all three spatial variables. In addition, the RRA Algorithm can calculate the sound-pressure level along individual ray paths for arbitrary, one-dimensional, depth-dependent speeds of sound.

SUMMARY: During fiscal year 1993 (FY 93), computer code was written to give the RRA Algorithm the capability to perform sound-pressure level (SPL) calculations along individual ray paths that are fast, accurate, and valid (i.e., finite) at both turning points and focal points for arbitrary, one-dimensional, depth-dependent speeds of sound. The SPL calculations do not require the use of Airy functions. At each computational step of the algorithm, both ray trace and SPL calculations are performed. Initial testing and validation of the SPL computer code was performed. In addition, the RRA Algorithm was given the capability to find eigenrays.

PUBLICATIONS: The research produced one journal article published, one journal article accepted for publication, two conference papers, and one presentation.

DOD KEY TECHNOLOGY AREA: Environmental Effects.

KEYWORDS: Three-dimensional ray acoustics, sound-pressure level calculations, underwater acoustics, undersea warfare.

SIGNAL-TO-NOISE ENHANCEMENT PROGRAM (SNEP)

RESEARCH AND SUPPORT

R.W. Adler, Senior Lecturer

D.Z. Wadsworth, Senior Lecturer

W.R. Vincent, Senior Researcher

Department of Electrical and Computer Engineering

Sponsor and Funding: COMNAVSECGRU

OBJECTIVE: Continued research and development in techniques to improve the signal-to-noise ratio at Navy receiving sites worldwide.

SUMMARY: Development of techniques and methodology for identifying and locating radio noise sources at NSG sites worldwide continued. The initial version of the Automated Performance Evaluation Technique for HF receiving sites was completed. Support was provided to NSG via review of pre-survey planning documentation, mitigation plans and authoring "Quick-Look" and final site-survey reports. Students and NSG site personnel were trained as part of the NSG support. A 2 1/2 day HF technical review of Factors that Affect Performance of Naval Receiving Sites was hosted for CNSG.

PUBLICATIONS: Vincent, W.R., "Revised Quick-Look Report, NSGD, Rota, Spain, CDAA Site," NSG Technical Report, January 1993.

Vincent, W.R., "SNEP Team Quick-Look Report at the Rota Spain CDAA Site," NSG Technical Report, 10 September 1993.

Vincent, W.R. and Munsch, G., "Power Line Noise Mitigation Handbook," Southwest Research Institute, January 1993.

Adler, R.W. and Vincent, W.R., "Factors Affecting the Performance of Naval Receiving Sites," Proceedings of the NSA 2nd Annual EMC Conference, April 1993.

Vincent, W.R. and Adler, R.W., "The Control of Intra-Site Sources of RFI/EMI at Naval Receiving Sites," Proceedings of the NSA 2nd Annual EMC Conference, April 1993.

CONFERENCE PRESENTATIONS: Adler, R. W., "The Design of Portable Antennas for Use in Locating Sources of Power-Line Noise During SNEP Site Surveys," at the Workshop on Factors Affecting the Performance of Naval Receiving Sites, Naval Postgraduate School, February 1993.

Adler, R.W., "The Possibility of Using Active Antennas at Naval Receiving Sites," at the Workshop on Factors Affecting the Performance of Naval Receiving Sites, Naval Postgraduate School, February 1993.

Perry, R.M., "Performance Evaluation of Modern HF Receivers," at the Workshop on Factors Affecting the Performance of Naval Receiving Sites, Naval Postgraduate School, February 1993.

Vincent, W.R., "Mitigation of Power-Line Noise," at the Workshop on Factors Affecting the Performance of Naval Receiving Sites, Naval Postgraduate School, February 1993.

Wadsworth, D.Z., "The Performance Evaluation Technique," at the Workshop on Factors Affecting the Performance of Naval Receiving Sites, Naval Postgraduate School, February 1993.

Vincent, W.R., "Examples of Internal

Noise Sources at Naval Receiving Sites," at the Workshop on Factors Affecting the Performance of Naval Receiving Sites, Naval Postgraduate School, February 1993.

Vincent, W.R., "Update on the Use of the Unified Barrier, Filter, Ground Technique to Control EMI/RFI from a PC Uninterruptable Power Supply (UPS)," at the Workshop on Factors Affecting the Performance of Naval Receiving Sites, Naval Postgraduate School, February 1993.

Adler, R.W. and Vincent, W.R., "Factors Affecting the Performance of Naval Receiving Sites," NSA 2nd Annual EMC Conference, Ft. Meade, MD, April 1993.

Vincent, W.R. and Adler, R.W., "The Control of Intra-Site Sources of RFI/EMI at Naval Receiving Sites," in

Proceedings of the NSA 2nd Annual EMC Conference, April 1993.

THESES DIRECTED: Davila, C.V., MAJ, Ecuadorian Air Force, "Comparison of HF Groundwave Propagation Models," Master's Thesis in Electrical Engineering, June 1993.

Mikros, E., LTJG, Hellenic Navy, "Mitigation of EMI/RFI Produced by a 1.2 KW Uninterruptable Power Supply," Master's Thesis in Electrical Engineering, September 1993.

DOD KEY TECHNOLOGY AREA: Sensors.

KEYWORDS: Electromagnetic Environmental Effects, Communication Systems, Man-made Noise.

**COMMUNICATION SYSTEM PERFORMANCE EVALUATION AND
HIGH LATITUDE PROPAGATION RESEARCH**

R. W. Adler, Senior Lecturer

W. R. Vincent, Senior Researcher

Department of Electrical and Computer Engineering

Sponsor and Funding: COMNAVSECGRU

OBJECTIVE: The goal of this sixth year of a continuing project was to conduct numerical analysis and experimental research in support of the Navy's requirement to site VLF through UHF communication antenna systems and support equipment in non-ideal locations such as polar and equatorial regions containing rugged terrain. A program of support for investigating the radiowave propagation characteristics of the polar (high-latitude) and the equatorial ionosphere was initiated in 1990 and continued in 1993.

SUMMARY: During this sixth year of the effort numerical models of antennas were developed for use at a new NSGD site in Shemya, AK. The electrical characteristics of the earth at several dozen NSG sites were measured and used to predict the effect of the ground beneath antennas deployed at the sites. Numerical models of commercial and NPS-built HF receiving antennas were developed and used to provide gain values for an ionospheric field strength model. Selected HF ionospheric propagation prediction codes were evaluated and compared to measured data for polar regions. NPS has been selected as the agency to oversee the development of theoretical and numerical models for the effects of irregular terrain on the performance of HF and VHF antennas. Penn State, LLNL, and NPS are in the last year of development of different types of terrain effects models. This project will integrate these models into the tri-service RF Mission Planning Workstation, being developed by the sponsor. A three-

day conference on Trans-Equatorial and Near-Equatorial Propagation was hosted at NSP in June 1993 for CNSG.

PUBLICATIONS: Vincent, W.R., "Man-Made Radio Noise at NRAD Site F17," NSG Technical Report, July 1993.

Vincent, W.R. and Adler, R.W., "Receiving Conditions at NSGD Shemya," NSG Technical Report, August 1993.

Vincent, W.R., "Radio Interference at the NPS Beach Receiver Site," NSG Technical Report, November 1993.

Vincent, W.R. and Adler, R.W., "Field Testing of Engineering Models of High-Dynamic Range Amplifiers," NSG Technical Report, December 1993.

Hunsucker, R.D., Rose, R.B., Adler, R.W., and Lott, G.K., "First Results from Alaska Auroral-E Propagation Experiment," Proceedings of the Solar Terrestrial Prediction Workshop, December 1993.

THESES DIRECTED: Milatos, G.D., LT, Hellenic Navy, "Evaluation of Site Effects on a High Frequency Direction Finding Single Site Location System," Master's Thesis in Electrical Engineering, March 1993.

McKinstry, J.W., LT, USN, "A Comparison of Trans-Equatorial Ionospheric Propagation Prediction from AMBCOM with Measured Data," Master's Thesis in Electrical Engineering, March 1993.

DOD KEY TECHNOLOGY AREA: Sensors,

Environmental Effects.

KEYWORDS: Electromagnetic
Environmental Effects, Communication
Systems, Man-made Noise, Antennas,
Radiowave Propagation.

FIELD STATION RESEARCH AND SUPPORT

R.W. Adler, Senior Lecturer
W.R. Vincent, Senior Researcher
D.Z. Wadsworth, Senior Lecturer
Department of Electrical and Computer Engineering
Sponsor and Funding: U.S. Army INSCOM

OBJECTIVE: The Army's SIGINT sites in Korea were subjected to an investigation by the NPS Signal Enhancement Lab staff to assess performance and to identify factors that were degrading performance.

SUMMARY: The Army's Field Station KOREA Tactical SIGINT site at Camp Humphrey required a thorough site performance investigation. NPS used techniques developed for the Naval Security Group HFDF sites to identify the key factors of the installation that must be addressed if site performance is to be restored and maintained. One of the three DMZ detachments was also visited by the NPS team to assess the state of performance and identify factors that degraded performance.

Recommendations for mitigation of noise sources which were located was made.

PUBLICATION: Vincent, W.R., Adler, R.W., and Wadsworth, D.Z., "Quick-Look Report, USA Field Station KOREA and DMZ Det. L," May 1993.

THESES DIRECTED: Lange, R.W., "Signal Acquisition and Analysis System," Master's Thesis in Electrical Engineering, June 1993.

Thomas, P.C., MAJ, USA, "A Comparison of Tactical and Strategic SOI Recovery," Master's Thesis in Electrical Engineering, September 1993.

Shanley, K.E., CAPT, USA, "An Amplitude Distribution Study of Selected Signals of Military Interest in the HF and VHF Bands (U)," Master's Thesis in Electrical Engineering, September 1993. (TOP SECRET Thesis)

DOD KEY TECHNOLOGY AREA: Sensors.

KEYWORDS: Electromagnetic
Environmental Effects, Communication
Systems, Man-made Noise.

AN ADAPTIVE ESTIMATION TECHNIQUE FOR
CONTROLLING ACTIVE POWER LINE CONDITIONERS

R.W. Ashton, Assistant Professor

Department of Electrical and Computer Engineering

Sponsor and Funding: NPS -- Research Initiation Program

OBJECTIVE: The implementation of a computer controlled system which at least in part actively compensates for harmonics in a power system with only the knowledge of the bus voltage.

SUMMARY: Due to the proliferation of power electronics devices in recent years, the amount of harmonic current injected into the power system is on the increase causing undesirable voltage waveform distortion. This distortion can cause additional losses in switchgear, rotating machines and transformers. Induction machines may vibrate due to parasitic torques or not develop sufficient starting torque. Capacitors will age faster due to excessive dielectric losses and stress. The goal of this research is to implement a system which can at least in part cancel harmonic currents in a power system with only the knowledge of the distorted bus voltage. The power system characteristics are established through an adaptive estimation technique which feeds and Active Power Line Conditioner with the proper control information

through an iterative process. The adaptive estimation system could also be used to supply power to a number of dc loads while at the same time compensating harmonics on a source ac bus. The whole system is controlled using a personal computer making it flexible to the needs of a particular power system.

PUBLICATION: Ashton, R.W. and Emanuel, A.E., "An Adaptive Estimation Method for Harmonic Voltage Minimization by Means of Line Conditioners," IEEE-PES, Summer Meeting, San Diego, CA, July 1991, Paper 91 SM 307-9 PWRD.

THESIS DIRECTED: Zupfer, J.E., LT, USN, "Optimal Adaptive Estimation Algorithm for Harmonic Current Reduction using Active Power Line Conditioners with limited Power," Master's Thesis in Electrical Engineering, December 1993.

DOD KEY TECHNOLOGY AREA: Other.

KEYWORDS: Line Conditioners, Harmonics, Adaptive Estimation, Active Filters.

DIGITAL SYSTEM DESIGN USING MULTIPLE-VALUED LOGIC

J.T. Butler, Professor

Department of Electrical and Computer Engineering

Sponsor and Funding: Naval Postgraduate School

OBJECTIVE: This project is directed toward the development of computer-aided design tools for multiple-valued circuits. Specifically, our effort is directed to further developing the simulated annealing technique, a search technique that can potentially produce exact designs, unlike heuristic approaches proposed by other researchers.

SUMMARY: Significant progress was made in four areas: 1) extension of the simulated annealing technique, 2) use of feedback in improving combinational logic circuit design, 3) use of the pseudo-Kronecker expansion for use in designing field-programmable logic arrays, and, 4) use of the universal literal for programmable logic array implementation.

Our present work on simulated annealing showed that this technique has significant promise in designing multiple-valued programmable logic arrays (MVL-PLA) [Butler, 1993]. An important benefit was the potential for finding the minimal size MVL-PLA in every case, a quality not shared by any other known approach. Our experimental results confirmed that it produced more efficient designs than any other known approach. However, simulated annealing is a search. We developed our algorithm so that the search could be conducted by multi-processors, and showed the relative merit of various numbers of processors [Yildirim, Butler, and Yang, 1993]. In conventional simulated annealing, there is the possibility that the search will occur repeatedly the same part of the

search space. To avoid this, we developed an algorithm that used history to decide on directions of search, and programmed it so that it would tend to move away from regions already searched. This is called a "tabu" search, because it labels as tabu moves that would take it to regions already visited. The result showed that we could either produce better results in the same time as classical simulated annealing or we could obtain comparable results in a shorter time.

A very interesting discovery was that feedback in combinational logic circuits could be used to significantly reduced circuit complexity in multiple-valued circuits [Butler and Sasao, 1994]. Feedback is commonly used in sequential circuits, circuits that "remember" past inputs. Most design engineers associate feedback only with sequential circuits. Our discovery was that feedback could be used to significantly reduce the complexity of multi-output circuits. Specifically, we showed a combinational circuit that had only six gates with feedback, while the same combinational circuit without feedback requires at least ten gates. We are very interested in pursuing this result to better understand it, so as to make it useful in Navy computing applications.

We have begun to study the design of field programmable gate arrays (FPGA's). Such devices have potentially better density capability than PLA's. We show an algorithm for the generation of near-minimal

designs that uses the Kronecker representation [Sasao and Butler, 1994].

In another effort, we showed that the use of the universal literal requires significantly smaller PLA area than the use of conventional "window" literals [Dueck and Butler, 1994].

PUBLICATIONS: Butler, J.T., "Research on Multiple-Valued Logic at the Naval Postgraduate School," Naval Research Reviews, Four/1992 One/1993, Vol. XLIV/Vol. XLV, pp. 2-8.

Yildirim, C., Butler, J.T., and Yang, C., "Multiple-Valued PLA Minimization by Concurrent Multiple and Mixed Simulated Annealing," in Proceedings of the 23rd International Symposium on Multiple-Valued Logic, pp. 17-23, May 1993.

THESES DIRECTED: Yildirim, C., LTJG,

Turkish Navy, "Multiple-Valued Programmable Logic Array Minimization by Concurrent Multiple and Mixed Simulated Annealing," Master's Thesis in Electrical Engineering, December 1992.

Wendt, C., LCDR, USN, "Multiple-Valued Programmable Logic Array Minimization by Solution Search Space," Master's Thesis in Electrical Engineering, December 1993.

DOD KEY TECHNOLOGY AREA: Computers, Design Automation.

KEYWORDS: Multiple-valued Logic, Computer-aided Design, Programmable Logic Arrays, Field Programmable Gate Arrays.

AUTOMATIC CONTROL OF AN EXTREMELY HIGH FREQUENCY ANTENNA

R. Cristi, Associate Professor

Department of Electrical and Computer Engineering

Sponsor and Funding: NISE West (formerly NAVELKX), Vallejo, CA

OBJECTIVE: This project aims at the design of a control system for rapid pointing of an antenna for EHF satellite communication. Primary objective is the estimation of offsets due to installation and construction tolerances, which affect the extremely tight pointing tolerance of two degrees. This is the second year of the project, began in FY 1992.

SUMMARY: The Navy Extremely High Frequency (EHF) antenna program utilizes a three axis antenna possibly mounted on a ship. Due to the very short wavelength involved, the positioning accuracy is very restrictive. In an effort to alleviate errors induced by machine and installation tolerances, very lengthy procedures are currently involved to properly align the antenna axis. An alternative way proposed in this research is to model the installation errors, and estimate the parameters from data collected on the control system during satellite tracking. To this goal the use of Euler's parameters has shown to be a very effective tool, and a complete mathematical model has been derived. The parameters are estimated by

robust least squares techniques on the basis of measurements from the inertial navigation of the ship (heading, pitch, and roll), the ephemeris of the satellite tracked and the commands given to the antenna's syncros. Data collected from the ship cruising at different headings provide sufficient information to insure that the technique is well conditioned and least sensitive to measurement errors.

PUBLICATION: Cristi, R., and Riling, W. D., "The Application of Euler Parameter Techniques to the Estimation and Correction of Offset Errors in an Extremely High Frequency (EHF) Antenna," NPS Technical Report, to be completed in February 1994.

OTHER: Software code is currently under development to be operational in the field.

DOD KEY TECHNOLOGY AREA: Communications Networking.

KEYWORDS: Communications, Control, Estimation.

**BASIC RESEARCH INTO WAVELETS AND THEIR APPLICATION
TO UNDERWATER SURVEILLANCE PROBLEMS**

M.P. Fargues, Assistant Professor

R. Hippenstiel, Associate Professor

Department of Electrical and Computer Engineering

Sponsor: NCCOSC, San Diego, CA

Funding: Naval Postgraduate School

OBJECTIVE: The goal of this continuing project is to investigate the properties of wavelets as they relate to underwater surveillance detection and identification problems.

SUMMARY: The study of the spectrum of signals, usually imbedded in additive noise, is important in SONAR/RADAR target detection and target identification. Time-Frequency (TF) transformations have been used to track time-varying signal variations. However, abrupt changes in the signal behavior cannot be simultaneously analyzed using TF transforms with long duration windows required for good frequency resolution and short duration windows required for good temporal resolution. A good compromise can be obtained with the Wavelet transform (WT) which is better able to track abrupt changes in signal behavior.

Four main implementations of the Wavelet transform have been considered. The "Discrete" continuous Wavelet transform, and three recursive discrete implementations of the WT. The discrete implementations considered were the decimated and undecimated A-Trous algorithm, and the Mallat algorithm. The Morlet wavelet was used for the A-Trous implementations.

Various synthetic signals have been examined using the different WT representations. In addition, the WT and TF implementations have been

applied to detect real-world Ultra-wideband (UWB) transient signals in non-stationary sea clutter and RFI interference. The UWB data was provided by the Radar Branch of NCCOSC, San Diego, CA. Results show that better performance is obtained using the A-Trous WT algorithm to detect the transient signals accurately while other TF representations, except for the Instantaneous Power Spectrum, were not able to detect the transients. Results also show that the choice of the number of voices, the center frequency and the rolloff coefficient of the Morlet wavelet may be used to enhance detection of the transients considered in the study.

CONFERENCE PUBLICATIONS: Fargues, M. P. and Brooks, W., "Ultra-Wideband Radar Transient Signal Detection using Time-Frequency and Wavelet Transforms," 4th Annual Navy R&D Information Exchange Conference, Naval Command, Control, and Ocean Surveillance Center, RDT&E Division, April 1993. (Unclassified Abstract published).

Fargues, M.P. and Brooks, W., "Application of Time-Frequency and Time-Scale Transforms Analysis to Ultra Wideband Radar Transient Signals," in Proceedings of the 4th SPIE Conference on Advanced Signal Processing Algorithms, Architectures, and Implementations, San Diego, 1993, Vol. 2027, pp.180-193.

THESIS DIRECTED: Hamlet, N.A., LT,

USN, "Comparison of Multiresolution Techniques for Digital Signal Processing," Master's Thesis in Electrical Engineering, March 1993.

OTHER: Wavelet Transform software designed to detect UWB transient in the presence of non stationary noise and RFI interference provided to the Radar Branch of NCCOSC, San Diego, CA, December 1992.

Journal paper in preparation.

DOD KEY TECHNOLOGY AREA: Electronic Devices.

KEYWORDS: Transient Detection, Wavelet Transform, Ultra-wideband Radar.

**INVESTIGATION OF SPECTRAL-BASED TECHNIQUES
FOR CLASSIFICATION OF WIDEBAND TRANSIENT SIGNALS**

M.P. Fargues, Assistant Professor

R. Hippenstiel, Associate Professor

Department of Electrical and Computer Engineering

**Sponsor and Funding: US Army Communications Center for
Signal Warfare**

OBJECTIVE: The goal of this project is to investigate and to implement, using Fortran, a fast and reliable way to classify wideband transient signals provided by the sponsoring organization.

SUMMARY: This study investigates two spectral-based procedures to efficiently classify certain classes of transient signals. Both schemes use a selected number of spectral coefficients for the classification procedure. The first approach considered uses spectral-based measures to distinguish between classes of transients. Four different measures are studied: the normalized cross-correlation coefficient, the Bhattacharyya distance, the divergence (related to the Kullback-Liebler number), and the modified normalized cross-correlation coefficient. Results show that the four measures can be used to classify the transients in different classes. They also indicate that a better performance is obtained when using the normalized cross-correlation measure (MNCC). Furthermore, the MNCC has a natural interpretation which allows for a simple interpretation by a human operator.

The second approach considered uses a back-propagation neural network (NN) approach. The NN is trained to distinguish between the different classes of signals provided by the sponsor. Results show that the NN

can be successfully trained to distinguish between the three different classes. Results are found to be consistent with those obtained using the spectral-based approach. The main drawback behind the NN approach is that it requires a large number of data to be trained with enough reliability.

PUBLICATIONS: Fargues, M.P. and Hippenstiel, R., "Investigation of Spectral-Based Techniques for Classification of Wideband Transient Signals," NPS Technical Report, NPSEC-93-008, 30 March 1993.

OTHER: Hippenstiel, R. and Fargues, M.P., "Classification of Wideband Transient Signals Using Spectral-Based Techniques," in Proceedings of the 27th Asilomar Conference on Signals, Circuits, and Computers, Pacific Grove, CA, October 1993.

Fargues, M.P. and Hippenstiel, R., "On Using Spectral-Based Measures to Classify Transient Signals," submitted to the 7th Signal Processing Workshop on Statistical Signal and Array Processing, to be held June 26-29, 1994, Quebec City, Canada.

DOD KEY TECHNOLOGY AREA: Electronic Devices.

KEYWORDS: Transient Detection/Classification, Spectral Distance Measure, Neural Network Application.

**MODELING, DETECTION, AND RECOGNITION TECHNIQUES
FOR UNDERWATER BIOLOGICAL DATA**

M.P. Fargues, Assistant Professor

R. Cristi, Associate Professor

Department of Electrical and Computer Engineering

Sponsor and Funding: None

OBJECTIVE: The goal of this continuing project is to investigate the applications of reduced-rank Autoregressive (AR) and Autoregressive-Moving Average (ARMA) modeling techniques to identification of biological underwater sounds.

SUMMARY: The first part of the research investigated the application of reduced rank AR modeling to the identification and classification of various underwater biological sounds. Two classification methods were considered. The first method considered investigated the use of backpropagation neural networks and reduced-rank AR models to identify biological sounds (such as humpback whale or killer whale sounds, for example). The second method investigated the use of spectral distances (such as the Symmetrized Itakura distance) for biological sound classification. The digitized acoustic data used for the research was obtained from audio tapes provided by the Hopkins Marine Station of Stanford University, Pacific Grove, CA. Results show that reduced-rank AR models can be used

successfully for biological sound classification both with the neural network configuration and the spectral distance approach. They also show that the spectral distance method is more restrictive as it requires a consistent set of sounds to be used successfully within a given species.

CONFERENCE PUBLICATION: Fargues, M. P., Cristi, R., and Vanderkamp, M., "Modeling and Classification of Biological Signals Using Least-Squares Prony-SVD AR Modeling," in Proceedings of the 36th Symposium on Circuits and Systems, Detroit, MI, 16-18 August 1993.

THESIS DIRECTED: Vanderkamp, M., LT, USN, "Modeling and Classification of Biological Signals," Master's Thesis in Electrical Engineering, December 1992.

DOD KEY TECHNOLOGY AREA: Electronic Devices.

KEYWORDS: Modeling, Underwater Signal Classification, Spectral Measures.

TRACKING SOURCES USING THE RANK-REVEALING QR FACTORIZATION

M.P. Fargues, Assistant Professor
Department of Electrical and Computer Engineering
Sponsor and Funding: None

OBJECTIVE: The goal of this continuing project is to investigate the application of the Rank-Revealing QR (RRQR) factorization to compute the signal information, and to take advantage of the simplicity of the QR update to track moving sources.

SUMMARY: Subspace decomposition methods are a powerful tool used in different areas of Signal Processing in which the signal information is usually obtained via eigen-based or SVD-based methods. These techniques are numerically very stable but expensive to update. The RRQR factorization provides an attractive alternative to accomplish subspace selection. We have refined the original algorithm proposed earlier, and have added an updating capability to the RRQR factorization. We have applied the resulting procedure to

the Direction Of Arrival (DOA) problem. Simulations show the performance of the "refined" adaptive RRQR-based technique is similar to that obtained using classical eigen-based techniques.

CONFERENCE PUBLICATION: Fargues, M. P. and Ferreira, M. P., "Adaptive RRQR-Based Factorization: Improving the Algorithm Tracking Capabilities," in Proceedings of the 26th Asilomar Conference on Signals, Systems, and Computers, Pacific Grove, CA, pp. 576-580, 26-28 October 1992.

OTHER: Journal paper in preparation.

DOD KEY TECHNOLOGY AREA: Electronic Devices.

KEYWORDS: DOA problem, Tracking, QR Factorization.

**RADIATION TOLERANT, HIGH-SPEED,
LOW-POWER, GALLIUM ARSENIDE DYNAMIC LOGIC**

**D.J. Fouts, Assistant Professor
Department of Electrical and Computer Engineering
Sponsor and Funding: SPANAR**

OBJECTIVE: Gallium Arsenide (GaAs) digital logic is now the technology of choice for high-performance, terrestrial-based computers and digital systems. Furthermore, research has shown that GaAs ICs are inherently hard against long-term exposure to high levels of ionizing radiation. This tends to make GaAs logic ideal for use in high-performance, space-based computers and digital systems. However, GaAs logic suffers from single event upset (SEU) problems in high radiation environments. The purpose of this three-year project is to study and quantify the SEU problem in GaAs logic, and to develop SEU-tolerant logic circuits. The effort is concentrating on dynamic logic, such as Two Phase Dynamic FET Logic (TDFL), because of its lower power consumption compared to static logic.

SUMMARY: Custom hardware for conducting radiation-induced, single event upset testing of GaAs dynamic logic has been designed, constructed, debugged, and tested. The hardware has been used to test existing GaAs dynamic logic circuits, especially Two-Phase Dynamic FET Logic (TDFL), for susceptibility to SEUs. With this information, predictions have been made about the error rate for GaAs dynamic logic circuits in a spacecraft in a geosynchronous orbit of approximately 22,500 miles. The initial testing phase of the project is now complete.

Results indicate that GaAs TDFL has about the same sensitivity to SEUs, or is perhaps a little less

sensitive, than the more common forms of GaAs static logic, such as Directly-Coupled FET logic (DCFL). This is a significant result because prior to this research, it was assumed that dynamic logic was more sensitive to SEUs than static logic. GaAs dynamic logic can now be used in place of GaAs static logic in new spacecraft systems, which will result in a significant power saving while maintaining high speed operation.

The preferred method for increasing SEU tolerance is to change the logic circuit at the transistor level by utilizing techniques such as redundancy. This frees the logic designer and the system architect from having to worry about SEUs, and is also less expensive than alternate methods, such as modifying the fabrication process to reduce transistor vulnerability. Therefore, ongoing research is attempting to develop dynamic logic circuits that are even more tolerant of the transient errors caused by SEUs. New, experimental GaAs logic circuits have been designed, and their operation has been simulated. A new, full custom, SEU test and evaluation IC has been designed and implemented, and is currently being fabricated. The purpose of the test and evaluation IC is to provide a method for evaluating the characteristics of the new logic circuits, both under normal environmental conditions and under radiation.

THESES DIRECTED: Wolfe, Kurtis A., LT, USN, "Single Event Upsets in Gallium Arsenide Two-Phase Dynamic

FET Logic," Master's Thesis in Electrical Engineering, December 1993.

Butler, Michael P., LCDR, USN, "Test Methods and Custom Hardware for Functional Testing of a High-Speed GaAs DRAM," Master's Thesis in Electrical Engineering, September 1993.

OTHER: The primary research output from this project has been custom hardware for conducting radiation-induced single event upset testing of GaAs dynamic logic. Also, in addition to the journal publication and the two related theses, bimonthly progress reports have been written and forwarded to the contract monitor. Several of these progress

reports have been supplied, by request, to an industrial corporation, and the results of this research have already been incorporated into the design of a new NASA satellite.

Fouts, D.J., "Single Event Upsets in Gallium Arsenide Dynamic Logic," IEEE Transactions on Nuclear Science, in review.

DOD KEY TECHNOLOGY AREA: Computers.

KEYWORDS: Radiation Hard Electronics, High-speed Computing, Space Electronics.

ULTRA WIDEBAND RADAR WAVEFORMS AND SIGNAL PROCESSING

G.S. Gill, Visiting Associate Professor

Department of Electrical and Computer Engineering

Sponsor and Funding: Office of Naval Research

OBJECTIVE: The goal of this project is to investigate waveforms for Ultra Wideband (UWB) radars and to identify suitable signal processing techniques. The study of wideband radar signals will also be included in this ongoing project.

SUMMARY: Initially, the generation of two different types of UWB waveforms was undertaken in this project. In the impulse waveform area an assessment was made of the technology which is being developed for high power microwave sources. Generation of high power impulses requires energy compression, that is, mechanisms to store and to release the energy. The technology of both aspects was examined.

The generation of a second waveform based on Fourier synthesis was also examined. Fourier based waveforms have several advantages over impulse waveforms such as accurate control of pulse shapes, pulse repetition interval, and the spectrum. This method was extended to the generation of binary coded waveforms. The generation of such codes is important as it allows for the use of longer pulses. These coded pulses contain more energy and improve the signal to noise ratio while still retaining the range resolution and other benefits of smaller pulse widths.

Also, ambiguity function techniques

were employed to investigate the UWB waveforms including the ones proposed and developed in this study.

THESES DIRECTED: Hsiao-Feng, C., "Waveform Generation for Ultra Wideband Radar System," Master's Thesis in Electrical Engineering, December 1993.

Leon Guerra, E., LT, Venezuelan Navy, "Generation of the Ambiguity Function for Ultra Wideband Waveforms," Master's Thesis in Electrical Engineering, June 1993.

Anderson, T., "An Assessment of Technology for High Power Microwave Impulse Sources," Master's Thesis in Electrical Engineering, June 1993.

OTHER: The following papers have been accepted for publication:

Gill, G. S., Hsiao-Feng, C., and Hall, J., "Waveform Synthesis for Ultra Wideband Radar," in Proceedings of the IEEE 1994 National Radar Conference, Atlanta, GA, March 1994.

Gill, G. S., "Signal Processing in Ultra Wideband Radars," in Proceedings of the SPIE Conference, Orlando, FL, April 1994.

DOD KEY TECHNOLOGY AREA: Sensors.

KEYWORDS: UWB, Waveforms, Signal Processing.

PANSAT COMMUNICATIONS SYSTEM DESIGN

T.T. Ha, Professor

Department of Electrical and Computer Engineering

Sponsors and Funding: SPANAR 40, Naval Postgraduate School

OBJECTIVE: The purpose of this research project is to design and build a breadboard direct sequence spread spectrum transceiver for the Petite Amateur Navy Satellite (PANSAT).

SUMMARY: A direct sequence spread spectrum (DSSS) transceiver for PANSAT was designed and was built. The transceiver was designed to operate at 9600 bps and has a pseudo-noise (PN) sequence length of 127. The system consists of six boards. Board 1 is the transceiver front-end. Board 2 contains IF and detection circuits. Board 3 is the receiver tracking circuit. Board 4 is the BPSK demodulator. Board 5 is the BPSK modulator. Board 6 contains the PN generator and differential encoder. Additionally, Board 6 acts as the interface between the transceiver and the digital control system.

THESES DIRECTED: Brown, A. O., III, LT, USN, "Communications Subsystem for the Petite Amateur Navy Satellite (PANSAT)," Master's Thesis in Electrical Engineering, September 1993.

Murray, T. J., LCDR, USN, "Four Frequency-Shift-Keying (4-FSK) Spread Spectrum Modulator and Demodulator," Master's Thesis in Electrical Engineering, March 1993.

Fritz, T. M., LT, USN, "A Bi-Phase Shift Keying (BPSK) Direct Sequence Spread Spectrum Modem for Petite Amateur Nave Satellite (PANSAT)," Master's Thesis in Electrical Engineering, December 1992.

DOD KEY TECHNOLOGY AREAS: Communications Networking.

KEYWORDS: Direct Sequence Spread Spectrum.

ANALYSIS USING BI-SPECTRAL RELATED TECHNIQUES

R. Hippenstiel, Associate Professor
Department of Electrical and Computer Engineering
Sponsor and Funding: Naval Command Control Ocean
Surveillance Center

OBJECTIVE: The goal of this project is to investigate the performance of a Bi-spectral related technique in detecting stationary and non-stationary spectral components.

SUMMARY: Earlier results indicate that a 1 $\frac{1}{2}$ -D spectral technique (a degenerate version of the Bi-spectrum) has potential Signal to Noise Ratio (SNR) gain over conventional techniques. This is partially due to the cumulant's response to Gaussian noise, which theoretically is zero. Using synthetic data and real ocean acoustic data the performance of the 1 $\frac{1}{2}$ -D technique is shown in comparison with a conventional spectrogram and an instantaneous power spectrum. The results of the simulation (synthetic

data) are supported by theoretical performance bounds.

PUBLICATION: Hippenstiel, R., "Analysis Using Bi-Spectral Related Techniques," NPS Technical Report NPSEC-93-020, 17 November 1993.

THESIS DIRECTED: McAloon, J.F., LT, USN, "Comparison of Higher Order Moment Spectrum Estimation Techniques," Master's Thesis in Electrical Engineering, 1993.

DOD KEY TECHNOLOGY AREA: Electronic Devices.

KEYWORDS: Signal Detection/Classification, Bi-spectrum, Cumulants, Instantaneous Power Spectrum.

STUDY OF WIDEBANDING TECHNIQUES FOR VHF ANTENNAS

**R. Janaswamy, Associate Professor
Department of Electrical & Computer Engineering
Sponsor and Funding: U.S. Army Communication and Electronics
Command**

OBJECTIVE: To investigate new techniques for widebanding VHF wire antennas over the frequency range 30--90MHz for digital radio applications.

SUMMARY: In the second year of this two-year project, feasibility studies were carried out for converting a simple monopole antenna into a wideband device capable of operating at any frequency in the 30--90 MHz range. Interest was in frequency agility rather than in wide instantaneous bandwidth. Two schemes were evaluated. In the first scheme, a simple monopole antenna operating over a ground plane was loaded with fast switching PIN diodes. The physical length of the monopole was varied by selectively switching ON or OFF the PIN diodes to present approximately the same electrical length over the entire frequency band. In the second scheme, a fixed length monopole antenna connected to parallel configuration of several matching networks which could be tuned electronically was considered. The matching networks, when switched selectively, will render the input impedance as well as the radiation pattern of the antenna relatively insensitive to frequency. Overall efficiency of the antenna, including

the insertion losses of the PIN diodes, current flow through the diodes, input impedance of the antenna, and radiation pattern of the antenna were all computed using an integral equation technique.

PUBLICATIONS: Thiem, K. and Janaswamy, R., "Widebanding Techniques for VHF Antennas II," NPS Technical Report NPSEC-93-007, March 1993.

Mohamed, D.A. and Janaswamy, R., "Design of a Continuous Resistively Loaded Monopole Antenna," NPS Technical Report NPSEC-93-011, May 1993.

THESIS DIRECTED: Thiem, Keem B., "Design of Broadband Wire Antennas for Frequency Hopping Applications," Master's Thesis in Electrical Engineering, March 1993.

OTHER: The investigator supervised a postdoctoral scholar from Egyptian Air Defense on work related to this project.

DOD KEY TECHNOLOGY AREA: Sensors.

KEYWORDS: Antennas, Broadbanding Techniques.

COMPUTER MODEL FOR PROPAGATION OVER IRREGULAR TERRAIN

R. Janaswamy, Associate Professor

Department of Electrical and Computer Engineering

Sponsor and Funding: Naval Security Group Support Activity

OBJECTIVE: To develop a computer model for predicting HF wave propagation over two and three dimensional terrain for sitting antenna systems under varying terrain situations.

SUMMARY: In the second year of this two-year project, we have developed a computer model of electromagnetic wave propagation over lossy, irregular terrain. Finite differences together with near-field radiation conditions were used to result in a rapid model whose execution time is of order $O(N)$ and whose storage requirement is of order $O(N^2)$. Half-space Green's function is used to further reduce the computational domain. The code computes the ground wave attenuation as well as sky wave patterns for an arbitrarily polarized, two dimensional current element in the presence of irregular and inhomogeneous terrain. The code is capable of handling huge terrain irregularities extending a few hundred wavelengths where other methods tend to be inefficient.

PUBLICATION: Janaswamy, R., "Application of the Measured Equation of Invariance to Wave Propagation Over Irregular, Inhomogeneous Ter-

rain," NPS Technical Report NPSEC-93-018, October 1993.

OTHER: Janaswamy, R., "A Fast Finite Difference Method for Propagation Predictions Over Irregular, Inhomogeneous Terrain," submitted to IEEE Transactions on Antennas Propagation, November 1993.

Janaswamy, R., "Application of the MEI Method to Wave Propagation Over Irregular Terrain," submitted to 1994 Joint IEEE AP-S International Symposium and URSI Meeting.

Mohamed, D. A. and Janaswamy, R., "Performance of Bayliss-Turkel type Radiation Conditions in TM Scattering by Conducting Cylinders," submitted to 1994 Joint AP-S International Symposium and URSI Meeting.

The investigator supervised a postdoctoral scholar from Egyptian Air Defense on work related to this project.

DOD KEY TECHNOLOGY AREAS: Design Automation, Environmental Effects.

KEYWORDS: EM Wave Propagation, Computational Electromagnetics.

RADAR CROSS SECTION AND SCATTERING STUDIES

D.C. Jenn, Associate Professor

Department of Electrical and Computer Engineering

Sponsor and Funding: Naval Postgraduate School

OBJECTIVE: The goal of this research was to further enhance the capabilities of a set of radar cross section (RCS) and radome analysis computer codes. The codes were originally developed during an earlier phase of this project, and have been delivered to several Navy labs (NRaD and the Naval Air Warfare Center in China Lake) as well as private contractors.

RCS analysis has been applied to axially symmetric reflector antennas, including their feeds. The code uses the method of moments to accurately model the interactions between the reflector surfaces and feed. A second code uses a method of moments solution to evaluate the defocusing and depolarization effects of curved radomes on microwave scanning antennas. This type of radome is frequently used in fighter aircraft and missile applications, and its presence can adversely affect the radar's performance. This solution is unique in that it allows the radome to be in the near field of the antenna. This situation is commonly encountered in practice, and cannot be handled by the usual radome models.

Verification and testing of the computer codes have been completed. Verification consisted of comparing computed data with previously published measured and calculated data. Measurements were performed on a AGM-86 HARM radome in the NPS anechoic chamber, and good agreement was obtained between the two.

Enhancements included revising

several of the code subroutines to allow a broader range of antenna amplitude and phase excitations. With these changes, low sidelobe and shaped beam antennas can be simulated.

PUBLICATION: Jenn, D.C., Fletcher, J.E., and Prata, A., "Radar Cross Section of Axially Symmetric Reflectors with Cavity-Backed Dipole Feeds," IEEE Transactions on Antennas and Propagation, Vol. AP-41, No. 7, July 1993.

CONFERENCE PRESENTATIONS: Jenn, D. C. and Pogorzelski, R. J., "Radiation from a Reflector in the Near Field of a Circular Aperture," IEEE AP-S International Symposium Digest, Vol. 3, p. 1334, 1993.

Prata, A., Johns, S., and Jenn, D. C., "The Modified Gaussian Beam as a Simple Near-Zone Reflector Antenna Feed Model," IEEE AP-S International Symposium Digest, Vol. 2, p. 796, 1993.

Jenn, D.C., Francis, R.M., and Klopp, K.A., "Computer Model for Axially Symmetric Dielectric Radomes in the Near Field of a Circular Aperture," Applied Computational Electromagnetics Symposium, p. 785, March 1993.

THESES DIRECTED: Chang, D.C., LT, USN, "Comparison of Computed and Measured Transmission Data for the AGM-88 HARM Radome," Master's Thesis in Electrical Engineering, September 1993.

Klopp, K.A., LT, USN, "Gain Loss and Pattern Degradation Due to Transmission Through Dielectric Radomes," Master's Thesis in Electrical Engineering, March 1993.

OTHER: Abstract submitted for 1994 IEEE AP-S Symposium.

DOD KEY TECHNOLOGY AREA: Sensors.

KEYWORDS: Radomes, Radar Cross Section, Antennas.

**A STUDY OF THE TEMPERATURE HISTORY OF THE
PANSAT VEHICLE OVER A SINGLE ORBIT**

A.D. Kraus, Senior Lecturer

**Department of Electrical and Computer Engineering
Sponsor and Funding: Naval Postgraduate School**

OBJECTIVE: The scientific objective of this research is to use an existing computer code to determine the temperature history of the Pansat vehicle over a single orbit. The extremes of temperature for both the sunlight and shadow zones have been approximated. It is expected that, because of the "thermal time constants," Pansat will never attain these extremes. The actual maximum and minimum temperatures have an impact on the design of the vehicle and must be evaluated before the vehicle design can be made firm.

SUMMARY: The impact of high and low temperatures on the skin of a space vehicle is well known. While the glory of an essentially zero degree Kelvin heat sink is appreciated, the contained equipment "sees" the skin as the heat sink.

PANSAT is an interesting vehicle in that most of its external surface is covered by solar panels and analysis of the steady state performance of the vehicle in both the sunlit and shadow zones have shown that the skin temperatures are somewhat high (in the sunlit zone) and somewhat low (in the shadow zone). These skin temperatures have an impact on the performance of the storage batteries used in conjunction with the solar cells.

However, because the vehicle will not

remain in either the sunlit or shadow zone long enough for the extreme temperatures to be reached, there is promise that the equipment will be exposed to more amenable skin temperatures. This, led to the work statement for this research: **USE AN EXISTING COMPUTER CODE TO DETERMINE THE SINGLE-ORBIT TEMPERATURE PATTERN FOR THE PANSAT VEHICLE.**

PANSAT has been modeled (based on up-to-date Engineering Information) both for steady state and transient thermal analysis. The steady state model has been run in order to determine the effect of any design changes since the last analysis. Weight-specific heat data has been incorporated into the steady state model in order to conduct the transient analysis. An iterative transient analysis has been performed with the analysis cutoff determined at the point where the temperatures at entrance at both the sunlight and shadow zones do not differ by more than 0.1 deg F for three successive passes.

DOD KEY TECHNOLOGY AREAS:
Environmental Effects, Software.

KEYWORDS: Space Vehicle, Orbital Effects, Sunlit and Shadow Zones, Computer Aided Design and Analysis.

THE FEASIBILITY OF A THERMOELECTRIC COOLER FOR
E-2C ENVIRONMENTAL CONTROL

A.D. Kraus, Senior Lecturer

Department of Electrical and Computer Engineering

Sponsor and Funding: NAS PAX River

OBJECTIVE: Determine the feasibility of using a thermoelectric air conditioner in the EC-2 aircraft. The ultimate objective is to minimize the impact of the discontinued use of Freon as a refrigerant in vapor compression air conditioning and refrigeration systems.

SUMMARY: Exhaustive calculations have been performed to determine the feasibility of the employment of a thermoelectric air conditioner to replace the freon air conditioner (environmental control system) presently employed on the E-2C aircraft. This discussion describes the studies conducted and provides a summary of the results obtained.

Initial contact was made via a phone call from LCDR Clifton at Patuxent River (hereinafter referred to merely as PAX River) to the writer. The statement of task was briefly described by LCDR Clifton; the object of the game was to find a reputable substitute for the existing Freon air conditioner aboard the aircraft. On July 15, 1993 the writer met with Tom Muratta of PAX River and Tim Springer of the Naval Warfare Center (hereinafter referred to as NWC) of Warminster, PA at PAX River. Several pertinent results occurred: 1) It was agreed immediately that the acoustic refrigerator that was being developed at the Naval Postgraduate School by Professor Garrett was not to be considered further. The acoustic refrigerator is still in the developmental stage and its size will not fit the allotted envelope; 2) It was agreed that Kraus would visit

Airesearch in Torrance, CA to determine the latest state-of-the-art in vapor compression refrigeration systems; 3) It was at this meeting that the possible use of thermoelectrics was first mentioned with a further proviso that vibration and shock requirements would probably preclude their use. It was also mentioned that the coefficient of performance to be obtained with the current technology (bismuth-telluride elements) was not at all comparable to that which could be obtained from a Freon vapor compression refrigeration system; 4) However, it was agreed that some rudimentary calculations regarding the thermoelectric air conditioner should be performed.

In September, Mr. Mike Cowell at Airesearch in Torrance, CA was visited. It was determined that there is a backup available to the Freon System using Hydrofluorocarbon HFC-236. In October, a meeting was held at NWC. The following was accomplished: 1) A detailed presentation on the Naval Postgraduate School Thermoacoustic Refrigerator was given; 2) A detailed presentation on cooling using thermoelectric elements and thermoelectric coolers was given; 3) While some rather cogent questions still remained, it was agreed that a search for a vendor who might be willing to build a prototype would be in order; 4) Several refinements were made to the ground rules that were used for the calculations.

In November 1993 a visit was paid to

the National Science Foundation (hereinafter referred to merely as NSF) in Arlington, VA and Thermotrex Corporation in Waltham, MA. The results of these visits are as follows: 1) At NSF, it was found that, in the event that a need for thermoelectric element improvement (research) program could be uncovered, NSF could fund it with a modicum of funds based on a two page letter proposal; 2) At Thermotrex, it was found that the calculations made demonstrated feasibility and that Thermotrex would be willing to undertake a funded study program that would result in a deliverable half-ton or quarter-ton prototype; 3) Thermotrex provided a copy of U.S. Patent 5,209,786 which showed their approach to the solution to the shock and vibration problem; It was found that Thermotrex is indeed conducting an ongoing research program to improve the figure of merit of the

cooler materials. It is felt that such an improvement in this figure of merit will help remove the possible uncertainty in the use of thermoelectrics.

THESIS DIRECTED: Clifton, W. F., LCDR, USN, "Thermoelectric Cooler Design," Master's Thesis in Astronautical Engineering, December 1992.

DOD KEY TECHNOLOGY AREA: Environmental Effects, Electronic Devices.

KEYWORDS: Thermoelectric, Bismuth-Telluride Semiconductor, Vapor Compression, Refrigeration, Air Conditioner.

WAVELETS TIME-FREQUENCY ANALYSIS OF SIGNALS AND SYSTEMS

A.W. Lam, Associate Professor

Department of Electrical and Computer Engineering

Sponsor and Funding: Naval Research Laboratory

OBJECTIVE: The goal of this project was to investigate wavelets and time-frequency analysis of signals and systems.

SUMMARY: We investigated wavelet-based time-frequency analytical techniques for transient signals and digitally modulated signals. Problems of particular interest were the detection and classification of multiple damped sinusoidal signals and chirped waveform in additive noise. The time-frequency decompositions of BPSK and QPSK signals, as well as spread-spectrum signals were obtained using a multi-resolutional approach.

OTHER: The results will be published in a forthcoming technical report.

DOD KEY TECHNOLOGY AREA:
Communications Networking.

KEYWORDS: Wavelets, Time-frequency Analysis, Digital Modulations, Spread-spectrum.

**SEQUENTIAL ACQUISITION SCHEMES FOR SSMA SYSTEMS WITH
GENERALIZED SIGNATURE SEQUENCES**

A.W. Lam, Associate Professor

Department of Electrical and Computer Engineering

Sponsor and Funding: Army Research Office

OBJECTIVE: The goal of this project was to investigate fast sequential acquisition schemes and system performance of spread-spectrum systems with complex signature sequences.

SUMMARY: This continuing research was to investigate sequential code sequence acquisition schemes for spread-spectrum multiple-access communications systems with generalized signature sequences. Fast, robust sequential code sequence acquisition schemes were developed and analyzed for systems with or without the presence of data modulation. Parametric and nonparametric schemes were proposed. Noncoherent and M-ary digital modulations were employed together with the generalized (nonbinary and polyphase) sequences. Product sequences that were efficient for rapid multiple-level sequential and/or parallel detections were proposed. The results were essential to the understanding of the system efficiency and reliability.

CONFERENCE PRESENTATIONS: Lam, A. W. and Tantaratana, S., "Mean Acquisition Time for Noncoherent PN Sequence Sequential Acquisition Schemes," in Proceedings of the IEEE Military Communications Conference, Boston, MA, pp. 784-788, October 1993.

Ozluturk, F. M., Tantaratana, S., and Lam, A. W., "Performance Bounds for DS/SSMA Systems with Noncoherent Signaling Schemes," in Proceedings of the IEEE Military Communications Conference, Boston, MA, October 1993, pp. 214-218.

THESIS DIRECTED: Misirlioglu, Levent, LT, Turkish Navy, "Acquisition Time Analysis of Noncoherent PN Sequence Acquisition Schemes," Master's Thesis for Engineer's Degree, September 1993.

OTHER: Three journal papers: "Noncoherent Sequential Acquisition of PN Sequences for DS/SS Communications With/Without Fading," "Probability of Bit Error for DS/SSMA Systems with MPSK Signaling and Complex Sequences," and "Performance of Noncoherent CDMA Systems with Complex Signature Sequences," were submitted and under review for publication. The investigator is also publishing a book (with S. Tantaratana), Theory and Applications of Spread Spectrum.

DOD KEY TECHNOLOGY AREA: Communications Networking.

KEYWORDS: Spread Spectrum, Sequential, Sequence Acquisition, CDMA.

HIGH PERFORMANCE COMPUTING TECHNOLOGY FOR
NAVY DIGITAL SIGNAL PROCESSING

C.-H. Lee, Professor

Department of Electrical and Computer Engineering

Sponsor and Funding: Naval Postgraduate School

OBJECTIVE: In this project a typical Navy digital signal processing (DSP) problem is run on a high performance parallel system. The goal is to develop a top down design methodology to partition a DSP problem into massively interconnected modules (MIM). We use the VHDL language to formulate the MIM modules so that algorithm decomposition were checked automatically.

SUMMARY: Beam Forming problems for acoustic signal detection were used as an example to develop the computation loads metrics. These metrics included computation bandwidth, communication bandwidth, memory bandwidth, FLOPS-IO ratio, and Latency-FLOPS product. Estimates of these metrics were useful in decomposing the total DSP tasks. From the software and hardware point of views, parallel systems with message passing were the most attractive approach for parallel processing. A demonstration was developed to show this design approach.

PUBLICATION: Lee, C.-H. and Sullivan, D., "Design of a Heterogeneous Parallel Processing System for Beam Forming," in Proceedings of the Workshop on Heterogeneous Processing, 13 April 1993, IEEE Computer Press Order No. 3532-02, Beverly Hills, CA, 1993.

CONFERENCE PRESENTATION: Lee, C.-H., "Beam Forming Using Parallel Workstations," the 4th Navy R&D Information Exchange Conference, NR&D, San Diego, CA, 13-15 April 1993.

THESIS DIRECTED: Fu, C. H., CAPT, Taiwanese Army, "An Implementation of Traffic Monitoring for UNIX Network Performance Management," Master's Thesis in Electrical Engineering, March 1993.

DOD KEY TECHNOLOGY AREA: Software.

KEYWORDS: High Performance Computing, Digital Signal Processing, Beam Forming.

MASSIVELY PARALLEL SYSTEM DESIGN

C.-H. Lee, Professor

**Department of Electrical and Computer Engineering
Sponsor and Funding: Naval Surface Warfare Center,
Dahlgren Division, White Oaks Detachment**

OBJECTIVE: The objective of this proposal is to showcase the systems engineering methodologies developed under the Systems Engineering Block. This goal is accomplished by assessing the fundamental tradeoff between development cost, life cycle cost, time and performance for a beamforming implementation problem. This tradeoff analysis concentrates on using the specific metrics formulated by the Systems Engineering Block.

SUMMARY: The Wide Aperture Array (WAA) served as a showcase for the application of the methodologies developed in the Systems Engineering Block. The large number of hydrophones in the array requires approximately 15 GFLOPS of sustained throughput for full detection capability. Efficiency, latency, performance monitoring and fault localization (PMFL), and real-time operating system overhead could establish a 100 GFLOP peak throughput requirement. These attributes enable the Wide Aperture Array in-board

functions to serve as a showcase for the methodologies developed by the Systems Engineering Block to assess and model real-time complex computer systems. In this research a Calibrated Mapping Performance Paradigm (CMPP) was developed to evaluate the partition results. Preliminary result is promising.

PUBLICATIONS: Lee, C.-H., "Top Down System Design Using VHDL," in Proceedings of the 6th Annual IEEE International ASIC Conference, Rochester, NY, 27 September 1993.

Lee, C.-H., "Predicting Parallel Computer Speed Up for Array Processing Applications in Simulation," in Proceedings of the 27th Asilomar Conference on Signal, Systems, and Computers, 1 November 1993.

DOD KEY TECHNOLOGY AREA: Software.

KEYWORDS: High Performance Computer, Digital Signal Processing, Beam Forming.

EM SCATTERING FROM A TUBULAR CYLINDER OF
ANISOTROPIC SURFACE IMPEDANCES

H.-M. Lee, Associate Professor

Department of Electrical and Computer Engineering

Sponsor and Funding: Sandia National Laboratories

OBJECTIVE: To investigate the effects of impedance coating on the scattering of electromagnetic waves by a body in the resonant region. To develop accurate computer codes as a reference standard.

SUMMARY: The electromagnetic scattering from a zero-thickness, perfectly conducting, circular, tubular cylinder of finite length with different anisotropic coatings on its inside and outside surfaces is investigated. The induced electric and magnetic surface current densities and the far field are obtained. Analytical expressions of the double series expansion coefficients of the kernels of the integral-differential equations of this problem are found and utilized in the computation to assure that extremely accurate numerical results can be obtained. These results will be used as a standard for validating numerical electromagnetic computation codes.

PUBLICATIONS: Lee, H.-M., "Scattering of a Coated Tubular Cylinder of Finite Length," in Proceedings of the Asia-Pacific Microwave Conference, Hsinchu, Taiwan, October 1993.

CONFERENCE PRESENTATIONS: Lee, H.-M., "Scattering of a Tubular Cylinder with Different Inside and Outside Surface Impedances," in Abstracts of the National Radio Science Meeting, Ann Arbor, MI, July 1993.

OTHER: Lee, H.-M., "Conditions for Vanishing On-Axis Backscattering of an Anisotropically Coated Cylinder," in preparation.

DOD KEY TECHNOLOGY AREAS: Software, Sensors.

KEYWORDS: Radar Cross Section, Impedance Coating, Anisotropic Material, Stealth.

**AIRBORNE COUNTERMEASURES AGAINST THE
LASER GUIDED SURFACE-TO-AIR MISSILE THREAT**

F.H. Levien, Senior Lecturer

Department of Electrical and Computer Engineering

Sponsor and Funding: Naval Air Systems Command

OBJECTIVE: Investigate airborne countermeasures capable of defeating the laser guided surface-to-air missile threat by defining first, the parameters of a postulated LSAM threat and engagement scenario, then identify flight scenario constraints, and design criteria for countermeasures, and finally look at current developmental alternatives, and choosing the best counter LSAM threat design.

SUMMARY: Two alternatives were identified as being mature enough to meet required real world constraints and operational performance criteria.

A plan for further development and flight testing was recommended so as to verify and expand preliminary results.

THESIS DIRECTED: Harned, R.C., LCDR, USN, "Airborne Countermeasure Against the Laser Guided Surface-to-Air Missile Threat (U)," Master's Thesis in Aeronautical Engineering, March 1993. (SECRET Thesis)

DOD KEY TECHNOLOGY AREAS: Sensors, Electronic Devices.

KEYWORDS: Lasers, Missiles, EW, Countermeasures.

**AIRBORNE COUNTERMEASURES TO ADVANCED
LASER BEAMRIDER SURFACE-TO-AIR MISSILES**

F.H. Levien, Senior Lecturer

Department of Electrical and Computer Engineering

Sponsor and Funding: Naval Air Systems Command

OBJECTIVE: Investigate, analyze, compare, and assess the effectiveness and feasibility of potential countermeasures to laser beamrider surface-to-air missiles.

SUMMARY: Laser-aided weapons are known to be widely manufactured and deployed by military organizations world wide. Of these systems, laser beam riders pose one of the most advanced and potentially lethal threats faced by aircraft today. This research developed a proposal and defined the optimal solutions to protect air crews from this threat.

Two concepts were identified as most promising, and their parameters presented.

THESIS DIRECTED: Mauro, J.B., LCDR, USN, "Airborne Countermeasures to Advanced Laser Beamrider Surface-to-Air Missiles (U)," Master's Thesis in Aeronautical Engineering, March 1993, (SECRET Thesis).

DOD KEY TECHNOLOGY AREAS: Sensors, Electronic Devices.

KEYWORDS: Lasers, Missiles, EW, Countermeasures.

AUGMENTATION OF THE IMPROVED MANY-ON-MANY (IMOM)
JAMMER EFFECTIVENESS MODEL

F.H. Levien, Senior Lecturer

Department of Electrical and Computer Engineering

Sponsor and Funding: Air Force Electronic Warfare Center

OBJECTIVE: This research was initiated to upgrade the Air Force Primary Modelling and Simulation Electronic Warfare Mission Planning System, IMOM, to include the jamming algorithm for the EA-6B, allowing the system to now be used jointly by Navy as well as Air Force mission planners.

SUMMARY: The specific programming enhancements provided to upgrade IMOM included a program change to AUTOJAM, written in ADA, and another providing analysis of jammer transmitters and modulations utilized by Navy/Marine Corps Prowler EA-6B aircraft. These

enhancements allow for automation of jammer planning and extension of the range of jammer choices in IMOM.

THESIS DIRECTED: Carpentier, W.A., LT, USN, "Augmentation of the Improved Many-on-Many (IMOM) Jammer Effectiveness Model (U)," Master's Thesis in Systems Engineering, September 1993, (SECRET Thesis).

DOD KEY TECHNOLOGY AREAS: Computers, Software, Human-System Interfaces.

KEYWORDS: EW, Radar, Modelling, Simulation.

TRANSPORTABILITY ISSUES OF UNINTENTIONAL
MODULATION-ON-PULSE EMITTER DATA
AMONG NAVY ESM PROCESSORS

F.H. Levien, Senior Lecturer

Department of Electrical and Computer Engineering

Sponsor: Naval Research Laboratory

Funding: Naval Postgraduate School

OBJECTIVE: To determine the feasibility of transporting unintentional Modulation-on-Pulse data that has been compiled by an NRL system utilizing the UYX-2 processor and the Grumman Aircraft Corporation AFX/P processor, to the systems planned for operational employment in the EA-6B ADVCAP aircraft.

SUMMARY: This study determined the process by which both UMOP processors functioned, and compared the resultant data from the same source, as recorded by each processor. It

then examined the feasibility of choosing either or both as a source of library inputs to an EA-6B application.

THESIS DIRECTED: Dauplaise, J.D., CAPT, USMC, "Transportability Issues of Unintentional Modulation-on-Pulse Emitter Data Among Navy ESM Processors (U)," Master's Thesis in Systems Engineering, September 1993, (SECRET Thesis).

DOD KEY TECHNOLOGY AREAS: Computers, Software, Design Automation, Sensors.

KEYWORDS: EW, Radar, UMOP,
Transportability, EA-6B.

**OPERATION OF AND POTENTIAL COUNTERMEASURES AGAINST
MISSILE SYSTEMS USING VISUAL IMAGING SEEKERS**

F.H. Levien, Senior Lecturer

Department of Electrical and Computer Engineering

Sponsor and Funding: Naval Air Systems Command

OBJECTIVE: To analyze the general operation of current and emerging missile systems using the visible spectrum and to evaluate proposed countermeasures that could be used to degrade missile effectiveness.

SUMMARY: The introduction of missile systems using visual imaging seekers has added a significant surface-to-air and air-to-air missile threat to all types of aircraft. This research evaluates seeker operation by focusing on target acquisition and tracking in the visible spectrum. Key technologies as well as the tracking algorithm are surveyed to

establish the vulnerabilities and weaknesses of these systems.

THESIS DIRECTED: Harvey, S.B., LT, USN, "Operation of and Potential Countermeasures Against Missile Systems Using Visual Imaging Seekers (U)," Master's Thesis in Aeronautical Engineering, March 1993, (SECRET Thesis).

DOD KEY TECHNOLOGY AREAS: Computers, Sensors, Human-System Interfaces.

KEYWORDS: Visual Imaging, EW, Missiles, Countermeasures.

ADVANCED SIGNAL PROCESSING TECHNIQUES

H. H. Loomis, Jr., Professor
Department of Electrical and Computer Engineering
and Space Systems Academic Group
M. Soderstrand, Visiting Professor
R. Bernstein, Visiting Professor
Department of Electrical and Computer Engineering
Sponsor and Funding: Secretary of the Air Force

OBJECTIVE: To investigate advanced signal processing algorithms and architectures for the detection and characterization of broadband communications signals in noise and interference.

SUMMARY: My principal accomplishment this year has been in the development, realization, and experimental verification of algorithms for the detection and characterization of cyclostationary signals, such as Phase Shift Keyed (PSK) signals. This work has resulted in one journal article, three conference papers, three presentations, and one thesis. Cooperative work with M. A. Soderstrand of UC Davis has resulted in continuing progress in the area of adaptive interference removal.

PUBLICATIONS: Brown, W. and Loomis, H., "Digital Implementations of Spectral Correlation Analyzers," IEEE Transactions on Signal Processing, Vol. 41, No. 2, pp. 703-720, February 1993.

Loomis, H.H., Jr. and Gardner, W. A., "Design of a Covert Communications Technique," MILCOM93 Classified Conference Record, MITRE Corp., Bedford, MA, Vol. 1, pp. 345-349, October 1993, (CONFIDENTIAL Paper).

Loomis, H.H., Jr. and Bernstein, R., Jr., "Realization of TDOA Estimation Architectures," in Proceedings of the Asilomar Conference on Signals,

Systems and Computers, November 1993.

Soderstrand, M.A., Chu, D.H., Chan, W., Laskani, M., and Loomis, H.H., Jr., "Multi-Rate Bandpass Filter Bank Implemented in QRNS Complex Arithmetic Using Parallel Multiple DSP Chips or ASICs," in Proceedings of the Asilomar Conference on Signals, Systems and Computers, pp. 801-806, November 1993.

CONFERENCE PRESENTATIONS: Loomis, H. H., Jr. (presenter) and Gardner, W. A., "Design of a Covert Communications Technique," MILCOM93, MITRE Corp., Bedford, MA, October 1993, (CONFIDENTIAL Presentation).

Loomis, H.H., Jr. and Bernstein, R., Jr., "Realization of TDOA Estimation Architectures," Poster paper presented at the Asilomar Conference on Circuits, Systems and Computers, Pacific Grove, CA, November 1993.

Loomis, H.H., Jr., "Applications of Cyclostationarity to Signal Detection and Geolocation," Office of Special Projects, Dept. of the Air Force, Washington, DC, 16 December 1993.

THESIS DIRECTED: Barksdale, C., LCDR, USN, "A Developing Spread Spectrum Prosecution Method," Master's Thesis in Systems Technology (Space Systems Operations), September 1993.

OTHER: Roberts, R.S., Brown, W.A., and Loomis, H.H., Jr., "A Review of Digital Spectral Correlation

Analysis: Theory and Implementation,"
Article 6 in Cyclostationarity in
Communications and Signal Processing,
William A. Gardner, Ed., IEEE
Press, New York, NY, (January 1994),
pp. 455-479, in press.

DOD KEY TECHNOLOGY AREA: Sensors.

KEYWORDS: Signal Detection, Source
Location, Cyclostationarity, High
Speed Computing.

PROJECT GUSTY ORIOLE

H.H. Loomis, Jr., Professor
Department of Electrical and Computer Engineering
and Space Systems Academic Group
R. Bernstein, Visiting Professor
Department of Electrical and Computer Engineering
Sponsor and Funding: Secretary of the Air Force

OBJECTIVE: To conduct research into
computer algorithms and architectures
for the processing of tactical
information. To provide support for
the course Space Systems 3001,
Military Applications of Space.

SUMMARY: Investigated Algorithms and
architectures of systems for the
production, distribution and analysis
of tactical information.
Investigated architectures of
spaceborne computer systems.
Investigated operational problems
concerned with the employment of
tactical information for decision
making and targeting. Continued
research into chokepoint shipping
analysis. Visited several military
satellite facilities to gather
information in support of SS3001.

THESES DIRECTED: Haefner, R.J., LT,
USN, "The Role of Chokepoint
Monitoring Operation in the Identifi-
cation and Tracking of Non-Combatant
Units," Master's Thesis in Systems

Technology (Space Systems
Operations), September 1993.

Helms, K.M., LT, USN, "Onboard
Processor Quality Assurance,"
Master's Thesis in Systems Technology
(Space Systems Operations), September
1993.

Leary, P.K., LT, USN, "Military
Applications of Space Advanced
Laboratory Development," Master's
Thesis in Systems Technology (Space
Systems Operations), September 1993.

DOD KEY TECHNOLOGY AREA: Computers.

KEYWORDS: Military Space,
Chokepoint, Shipping Monitoring,
Tracking and Correlation.

ON-ORBIT ANNEALING OF SATELLITE SOLAR PANELS

S. Michael, Associate Professor

Department of Electrical and Computer Engineering

Sponsor and Funding: SPANAR, Space and Naval Warfare Command

OBJECTIVE: Investigate the possibility of on-orbit annealing of satellite's InP and GaAs Solar Cells using the new Minority Carriers Annealing Techniques.

SUMMARY: This is a continuation of the ongoing research on Photovoltaic Power Technology. Research tasks include the development and completion of the Solar and Radiation Laboratory, the development of the microprocessor based Photovoltaic experiment as well as testing of the solar panels for the PANSAT satellites. The tasks also include investigation of Photovoltaic current annealing processes and other topics of electron and proton radiation effects on GaAs, InP and Si devices.

PUBLICATIONS: Michael, S., "Analysis of Radiation Damage and Annealing Process in Advanced GaAs and InP Solar Cells Using DLTS Techniques," Proceedings of the 11th International Photovoltaic Solar Energy Conference, October 1992.

Walters, R.J., Summers, G.P., and Bruening, J., "A Detailed Study of

the Photo-Injection Annealing of InP Solar Cells," in Proceedings of the Twelfth Space Photovoltaic Research and Technology Conference, NASA Lewis Research Center, Cleveland, OH, 20-22 October 1992.

CONFERENCE PRESENTATION: Michael, S., "Analysis of Radiation Damage and Annealing Process in Advanced GaAs and InP Solar Cells Using DLTS Techniques," 11th International Photovoltaic Solar Energy Conference, October 1992.

THESIS DIRECTED: Bruenin, J., LT, USN, "Analysis of Radiation Damaged and Annealed Gallium Arsenide and Indium Phosphide Solar Cells Using Deep Level Transient Spectroscopy," Master's Thesis in Aeronautical Engineering, September 1993.

DOD KEY TECHNOLOGY AREA: Electronic Devices, Environmental Effects, Propulsion and Energy Conversion.

KEYWORDS: Space Radiation Effects, Satellites, Annealing, Radiation Hardening.

UNINTERRUPTABLE POWER SUPPLY DESIGN FOR COMMUNICATION SYSTEM

S. Michael, Associate Professor
Department of Electrical and Computer Engineering
Sponsor and Funding: Marine Corps System Command (DFMQ),
Quantico, VA

OBJECTIVE: To develop and design an Uninterruptable power supply for the MRK-142 on board Marine HMMV.

SUMMARY: This research is proposed to Design and Develop a prototype Uninterruptable Power Supply. The result would be an improved Power Distribution Panel that will provide the capability to manually switch between two AC sources, to the HMMV DC battery/alternator or other DC sources. This would be accomplished with no interruption in the AN/MRC-

142 communication system operation.

OTHER: Prepared a Video Tape as a manual for the use of the designed system.

Thesis is in preparation.

DOD KEY TECHNOLOGY AREA: Electronic Devices, Propulsion and Energy Conversion.

KEYWORDS: Uninterruptable Power Supply, Reliable Communication System.

HYBRID POWER SYSTEM FOR REMOTE COMMUNICATION STATIONS

S. Michael, Associate Professor
Department of Electrical and Computer Engineering
Sponsor and Funding: U.S. Coast Guard, Coast Guard Island,
Alameda, CA

OBJECTIVE: Developing a Photo-voltaic/Windturbine Hybrid Power System to provide electrical power to the Coast Guard Communication Stations in different Alaska remote sites.

SUMMARY: This research is proposed to investigate the possibility of incorporating different power systems to provide electrical power to Alaska's Coastal Voice Distress Network, operated by the U.S. Coast Guard. Research tasks include investigating the performance of Thermo-Electric Generators (TEG) providing power to the current systems. Investigating present and new power sources technologies.

Investigating different energy resources available at the proposed stations sites, including seasonal changes studies. Developing and designing reliable hybrid power systems capable of utilizing available energy sources at these sites. These systems would probably incorporate wind power, solar power and TEG systems.

THESIS DIRECTED: Pietras, C., LCDR, USN, "Hybrid Power System for Remote Communications Stations," Master's Thesis in Electrical Engineering, September 1993.

DOD KEY TECHNOLOGY AREA: Energy Storage, Environmental Effects,

Propulsion and Energy Conversion.

KEYWORDS: Solar Cells, Wind Power,
Hybrid Power System.

ADVANCED ANALOG VLSI DESIGN FOR IC's AND
NEURAL NETWORKS IMPLEMENTATIONS

S. Michael, Associate Professor

Department of Electrical and Computer Engineering

Sponsor and Funding: Naval Postgraduate School

OBJECTIVE: To design and implement an advanced Stray insensitive Switched-Capacitor, Analog VLSI as a building block for future Neural networks

SUMMARY: Development of high performance, low sensitivity analog VLSI is proposed in this research. A novel technique for designing advanced active building blocks essential for VLSI implementation is investigated. The new designs are based on the Composite Amplifiers, previously introduced by the investigator. The research goal is to develop Stray-Insensitive Switched-Capacitor analog building blocks that will be used in the follow-up project to design and build a high performance analog VLSI circuits. The availability of such novel designs would play a key role in the practical implementations of Neural Networks.

PUBLICATIONS: Michael, S., "Programmable Sampled Data Filter with Low Sensitivity Implementation," in Proceedings of the 4th International Conference on Advances in Communications and Control, Rhodes, Greece, June 1993.

Michael, S., "Low Sensitivity Switched-Capacitor Networks with Reduced Parasitic Effects," in Proceedings of the 36th Midwest

Symposium on Circuits and Systems, Detroit, MI, August 1993.

CONFERENCE PRESENTATIONS: Michael, "Programmable Sampled Data Filter with Low Sensitivity Implementation," International Conference on Advances in Communications and Control, Rhodes, Greece, June 1993.

Michael, S., "Low Sensitivity Switched-Capacitor Networks with Reduced Parasitic Effects," 36th Midwest Symposium on Circuits and Systems, Detroit, MI, August 1993.

THESES DIRECTED: Bingham, E., CAPT, USMC, "Stray Insensitive Switched Capacitor Composite Amplifiers," Master's Thesis in Electrical Engineering, March 1993.

Crowell, R., LCDR, USN, "Digitally Programmable Composite Operational Amplifier Applications," Master's Thesis in Electrical Engineering, September 1993.

Hudson, B., CAPT, USA, "Gallium Arsenide MESFET Operational Amplifier to be used in Composite Operational Amplifier Design," Master's Thesis in Electrical Engineering, December 1993.

Silvernagle, G., LT, USN, "A VLSI Implementation of A CMOS Stray Insensitive Switched-Capacitor

Composite Operational Amplifiers,"
Master's Thesis in Electrical
Engineering, December 1993.

DOD KEY TECHNOLOGY AREA: Electronic
Devices.

KEYWORDS: Analog VLSI, Low
Sensitivity, Switched-capacitors,
Neural Networks Application.

TIME DOMAIN LOCALIZATION

J.H. Miller, Associate Professor

Department of Electrical and Computer Engineering

C.-S. Chiu, Associate Professor

Department of Oceanography

Sponsor and Funding: NUWC New London

OBJECTIVE: The goal of this work is the determination of source range and depth in an ocean acoustic waveguide given a time domain representation of a source-generated signal. This is the second year of the project.

SUMMARY: In this reporting period, algorithms were developed for the passive localization of transients generated by a submarine. These algorithms are tested with actual data acquired by a submarine spherical array. The algorithms rely on the exploitation of knowledge of the transfer function of the shallow ocean waveguide between the emitting submarine and the receiving submarine. One algorithm, autocorrelation matching, performs adequately in localizing transients at three different ranges from 1800 to 3850 m.

THESES DIRECTED: Nicholson, C. L., LCDR, USN, "Localization of Acoustic Transients in Shallow Water Environments," Master's Thesis in Electrical Engineering, December 1992. LCDR Nicholson was selected for the Space and Naval Warfare Systems Command Award in Electronic Systems Engineering.

Schultz, J.L., LT, USN, "Implementation of a Time Domain Localization Algorithm in the AN/SQR-10 Tactical Towed Array Sonar System," Master's Thesis in Applied Science, December 1992.

DOD KEY TECHNOLOGY AREA: Sensors.

KEYWORDS: Transient, Localization, Submarine.

FIELD CANCELLATION USING A COUNTER-EMF APPROACH

M.A. Morgan, Professor & Chairman

Department of Electrical and Computer Engineering

Sponsor and Funding: Naval Postgraduate School

OBJECTIVE: This two-year project investigates a practical approach for reducing bistatic radar cross section using active cancellation.

SUMMARY: The counter-EMF technique appears most promising at radar frequencies below which passive measures such as shaping and absorbing materials are inoperative. Thus the active approach may dovetail in frequency with the more conventional methods to provide ultra-wideband RCS reduction against future radar designs, including impulse radars. The first year has been devoted to analytical studies and numerical simulations to consider tradeoffs of RCS reduction vs. frequency range for number and placement of canceler modules using wire models of aircraft structures. Typical bistatic RCS reductions of at least 20 dB over all aspects are observed around frequencies corres-

ponding to canceler spacings of one-fourth wavelength. Reductions of 30-40 dB are observed for still lower frequencies. Gradual degradation of performance is observed as frequency is increased until canceler spacing approaches one-half wavelength, at which point the system fails dramatically. The second year will provide more detailed numerical modeling and begin to design scale model experimental validations.

OTHER: Morgan, M. A., "Counter-EMF Active Reduction of Bistatic Radar Scattering," in preparation for IEEE Transactions on Antennas and Propagation.

DOD KEY TECHNOLOGY AREA: Sensors.

KEYWORDS: Active Cancellation, RCS Reduction, Low Observables.

ULTRA-WIDEBAND IMPULSE ANTENNA DESIGN

M.A. Morgan, Professor & Chairman

R.C. Robertson, Associate Professor

Department of Electrical and Computer Engineering

Sponsor and Funding: U.S. Army CECOM Signals Warfare Directorate

OBJECTIVE: Goals of this project are to conduct engineering designs, develop test procedures, and to construct and test prototypical ultra-wideband impulse receiving antennas.

SUMMARY: Impulse antennas are antennas that are intended to either transmit or receive very short pulses of electromagnetic energy. As is well known, short pulses have extremely wide bandwidths; hence, impulse antennas by their very nature must be wideband. However, in order to maintain signal fidelity, it is also very important that the impulse antenna not introduce significant phase distortion into the signal. What is required is a wideband antenna with not only a constant magnitude response across the bandwidth but also linear phase shift resulting in minimal dispersion of the signal. Research into impulse antennas has been very intense for a number of years now, with a major application being the measurement of EMP signals resulting from nuclear explosions. A TEM horn antenna for receiving impulse signals with a

theoretical bandwidth of 100MHz--5GHz was designed, constructed and tested in 1993. Follow-on work planned in 1994 will consider designs for increasing antenna gain and bandwidth, while reducing the physical size of the antenna structure.

PUBLICATIONS: Robertson, R.C. and M.A. Morgan, "Ultra-Wideband Impulse Antenna Study and Prototype Design," NPS Technical Report NPS-EC-93-010, March 1993.

Morgan, M.A., "Scale Model Ultra-Wideband Impulse Radar," SPIE OE/LASE '93 Conference, Los Angeles, CA, 16-23 January 1993.

Morgan, M.A., "Ultra-Wideband Scale Model Impulse Radar," Progress in Electromagnetics Research Symposium (PIERS), Pasadena, CA, 12-16 July 1993.

DOD KEY TECHNOLOGY AREA: Sensors.

KEYWORDS: Ultra-wideband, Impulse Antennas, TEM Horns.

**ALGORITHMS FOR ASSESSING THE EFFECTIVENESS OF SHIPBOARD
COUNTERMEASURES AGAINST ANTI-SHIPPING MISSILE PLATFORMS**

P.E. Pace, Assistant Professor

Department of Electrical and Computer Engineering

**Sponsor and Funding: Tactical Electronic Warfare Division
Naval Research Laboratory**

OBJECTIVE: The objective of this research is to improve the process for evaluating hardware-in-the-loop and field test performance results. As part of this objective, new algorithms to measure the overall EW systems utility and effectiveness were to be developed.

SUMMARY: Hardware-in-the loop data from NRL's Central Targeting Simulator facility was obtained. This data demonstrates the response of various anti-shiping missile platforms (open loop/closed loop) in an electronic countermeasures environment. Simulation models of various missiles were constructed to incorporate this data to measure the effectiveness of the various ECM waveforms. After discussion with the Integrated EW Simulation Scientists, it was determined that incorporation

of the true seeker response could add additional confidence in the simulation results. It was decided to obtain characterization data corresponding to the seeker currently under study. Incorporation of this type of analysis into the simulation models (reverse engineering) is expected to further increase the accuracy of the performance predictions.

OTHER: Presentation, "Initial Progress (U)," Integrated EW Simulation Branch, Tactical EW Division, NRL, 30 September 1993.

DOD KEY TECHNOLOGY AREA: Sensors.

KEYWORDS: Anti-shiping Missiles, Electronic Countermeasures, Simulation.

**HIGH RESOLUTION DIRECT DIGITIZATION AND OPTICAL
TELEMETRY OF ANTENNA SIGNALS**

P.E. Pace, Assistant Professor

Department of Electrical and Computer Engineering

Sponsor and Funding: Space and Naval Warfare Systems Command

OBJECTIVE: The objective of this research was to investigate the feasibility of directly digitizing, wideband antenna signals using high-resolution techniques to achieve 14-bits resolution.

SUMMARY: An optical interferometer was borrowed from the Optical Sciences Division at NRL to initiate the effort in the NPS optical laboratory. Measurements of the device performance were taken and a 14-bit design based on a new symmetrical number system was developed. Since the interferometer had a V-PI of four volts it was decided that the interferometer was in adequate for 14-bits. After several discussions with NRL and the research team, it was decided to develop a prototype 8-bit design to study the issues that could possibly give problems. Digital hardware consisting of a logic block and an erasable programmable memory was constructed to decode the sampled analog signal into a more familiar binary output. It was also decided to hold discussions with NRL and investigate the possibility of fabricating a new interferometer having a V-PI of 0.2 volts which can instrument the 14-bits.

PUBLICATIONS: Pace, P.E., Ramamoorthy, P.A., and Styer, D., "A Preprocessing Architecture for Resolution Enhancement in High-Speed

ADC's," IEEE Transactions on Circuits and Systems, accepted for publication, January 1994.

Pace, P. E. and Styer, D., "High-Resolution Encoding Process for an Integrated Optical Analog-to-Digital Converter," Optical Engineering, accepted for publication, December 1993.

CONFERENCE PUBLICATIONS: Esparza, J. A. and Pace, P.E., "A Preprocessing Architecture for Resolution Enhancement in High-Speed Analog-to-Digital Converters," IEEE International Symposium on Circuits and Systems, paper No. 22.20, Chicago IL, 3 May 1993.

Pace, P.E., "Research in High-Speed ADCs at the Naval Postgraduate School," Tri-Service Digital RF Memory and Digital Receiver Workshop (U), Atlanta GA, 15 July 1993.

OTHER: Presentation, Pace, P.E., "High Resolution Techniques for Integrated Optical Guided-Wave ADCs," seminar at the University of California, Davis, 22 October 1993.

DOD KEY TECHNOLOGY AREA: Sensors, Electronic Devices.

KEYWORDS: Symmetrical Number System, Analog-to-digital Conversion, Preprocessing, Optics.

SURFACE MODE PROCESSING FOR TARGET DETECTION AND DECLARATION

P.E. Pace, Assistant Professor

Department of Electrical and Computer Engineering

Sponsor and Funding: Hughes Missile Systems Company

OBJECTIVE: The objective of this research was to experimentally evaluate the trade-offs between an inverse MTI filtering approach and a DFT filter bank approach to detect surface targets in sea clutter.

SUMMARY: Trade-offs in performance versus hardware complexity were evaluated for two search processor configurations for several slow moving targets of various size buried in recorded sea clutter data. Several variations were investigated for each approach. A retrofit of the current Phalanx hardware to perform this search/detection processing was studied and an optimal inverse filter was constructed that could easily be implemented in the currently configured hardware. Overflow effects and truncation noise levels were numerically evaluated.

PUBLICATIONS: Pace, P.E. and Taylor, L.L., "False Alarm Analysis of the Envelope and Envelope Approximation GO CFAR Processor," IEEE Transactions on Aerospace and Electronic Systems, accepted June 1993.

Pace, P.E. and Brewer, D.B., "16-bit Inverse MTI for Low Velocity Target

Acquisition (U)," NPS Technical Report NPSEC-93-023, to Hughes Missile Systems Company, (CONFIDENTIAL Report), December 1993.

PUBLICATIONS: Pace, P.E. and Taylor, L.L., "Radar Signal Processing for the Determination of Individual Projectile Characteristics (U)," in Proceedings of the 30th Annual Tri-Service Radar Symposium, Paper No. 93.53, 23 June 1993, (CONFIDENTIAL Paper).

THESES DIRECTED: Bowman, P.J., LT, USN, "Combatting Inherent Vulnerabilities of CFAR Algorithms and a New Robust CFAR Design," Master's Thesis in Electrical Engineering, September 1993.

Doo Jong, K., CAPT, Korean Army, "New Binary Integration Strategies and Corresponding R90 Calculations," Master's Thesis in Electrical Engineering, September 1993.

DOD KEY TECHNOLOGY AREA: Sensors.

KEYWORDS: Phalanx, Close-in-weapon-system, Surface Mode Signal Processing, Sea Clutter.

PASSIVE EVALUATION OF IR TARGETS

R.J. Pieper, Associate Professor

Department of Electrical and Computer Engineering

Sponsor and Funding: Naval Postgraduate School

OBJECTIVE: To investigate, using both experimental measurements and computer modeling, viable schemes for passive characterization of target range and other features based on measurements in the IR bands.

SUMMARY: This project was initiated in Quarter 3 of FY93 and is under continuation into FY94. A method for passive ranging based on the principle of triangulation was investigated. The sensitivity of the range prediction to variation in the bearing accuracy was evaluated in terms of the distance between baselines, target orientation, and range to the target. The dual baseline system was shown to have significant tactical advantages over a single baseline. RelatedIRST work which included system modeling and target signature enhancement was also investigated.

THESIS DIRECTED: Chan, P.M.,
"Experimental investigation of Infra-

red Polarization Effects in Target and Background Discrimination," Master's Thesis in Electrical Engineering, June 1993.

OTHER: Technote delivered to John Hopkins University, Applied Physics Lab to appear as an NPS Technical Report: Pieper, R.J. and Cooper, A. W., "A Triangulation Method for Passive Ranging," Technote NACIT-94-1; delivered JHU/APL, November 1993.

Pieper, R.J. and Cooper, A.W., "A Visibility Model for MRTD Prediction," accepted for presentation at SPIE Symposium on Infrared Imaging Systems: Design, Analysis, Modeling, and Testing V, Orlando, April 1994; accepted for publication in SPIE proceedings.

DOD KEY TECHNOLOGY AREA: Sensors.

KEYWORDS: Infrared Systems, Sensors, Polarization Effects.

PROPAGATION OF TRANSIENT WAVES

J. Powers, Professor

Department of Electrical and Computer Engineering

Sponsor and Funding: Naval Postgraduate School

OBJECTIVE: To study the predicted propagation properties of transient acoustic and optical waves in an effort to understand the propagation of very short duration waves and to use such waves in imaging applications.

SUMMARY: With the ability to generate short-duration sound and light pulses comes the requirement to be able to model and understand the propagation of these waves. Unlike most line-integral techniques presently available, these models should be computationally efficient.

We have developed a method of simulating acoustic propagation in linear homogeneous media based on Fourier transform techniques. The propagation transfer function represents a time-varying spatial filter that increasingly attenuates the higher spatial frequencies of the wave as time increases.

Effort focused on implementing the model on a large-memory microcomputer using the commercial program, MATLAB, and in using visualization tools to

display the calculated four-dimensional wave (three space dimensions and time). Currently, we are constructing a computer-controlled experimental data-collection system to measure experimental acoustic data fields to confirm the technique.

PUBLICATION: Powers, J.P., "Acoustic Propagation Modeling Using MATLAB," NPS Technical Report NPS-EC-93-014, September 1993.

OTHER: Powers, J.P., Reid, W., Upton, J.G., and Van de Veire, R., "A Comparison of the Transient Propagation Properties of Gaussian and Bessel Waves," to be published in Acoustical Imaging, Vol. 21, J. P. Jones, ed., Plenum Press, in 1994.

THESIS DIRECTED: Gatchell, Peter, LTJG, USN, "Experimental Measurement of Acoustic Wave Propagation," Master's Thesis in Electrical Engineering, to be completed in June 1994.

DOD KEY TECHNOLOGY AREA: Sensors.

KEYWORDS: Acoustics, Wave Propagation, Transient Waves, Optics.

DEVELOPMENT OF PROTOCOLS FOR MARITIME MOBILE COMMUNICATIONS

R.C. Robertson, Associate Professor

T.T. Ha, Professor

Department of Electrical and Computer Engineering

**Sponsor and Funding: U.S. Coast Guard Research and
Development Center**

OBJECTIVE: The purpose of this research program is to determine what Open System Interconnection (OSI) data communication protocols can be used to provide effective and efficient data communications for radio-based maritime mobile services (including satellite systems).

SUMMARY: Data communications are becoming more extensively used in the maritime mobile services. With no current general protocol profile that can be used for data communications between mobile services, protocols that adhere to the OSI standards need to be developed. The implementation of such protocols will allow multiple shipboard equipment to communicate via a shipborne network and then transmit the data to a shore-based network in an efficient manner. Automatic Repeat reQuest (ARQ) techniques are often used by packet switching networks to provide error free communication links between network nodes. Information through-

out is highly link dependent; as the noise or interference on the link increases, throughput decreases. To improve throughput on a packet switching communications network, an adaptive ARQ strategy was developed and applied to the Stop-and Wait (SW) protocol. A comparison of the throughput efficiencies of the simulated adaptive SW protocol with the non-adaptive SW protocol shows a marked improvement in throughput when the communication links are subjected to high channel bit error rates.

PUBLICATION: Borchardt, R.L., Ha, T.T., and Robertson, R.C., "Development of Protocols for Maritime Mobile Communications," NPS Technical Report NPSEC-93-021, November 1993.

DOD KEY TECHNOLOGY AREA: Communications Networking.

KEYWORDS: Open System Interconnect (OSI), Protocols, Data Communications Network.

**PERFORMANCE OF FAST FREQUENCY-HOPPED
M-ary FREQUENCY-SHIFT KEYING SYSTEMS OVER
FADING CHANNELS WITH PARTIAL-BAND INTERFERENCE**

R.C. Robertson, Associate Professor

Department of Electrical and Computer Engineering

Sponsor: Naval Postgraduate School

OBJECTIVE: The goal of this project is to determine the Electronic Counter-Counter Measures (ECCM) potential of various FFH/MFSK communications systems under conditions of worst case hostile Electronic Counter Measures (ECM) and fading channels.

SUMMARY: The performance of an M -ary orthogonal frequency-shift keying (MFSK) communication system employing fast frequency-hopped spread spectrum waveforms transmitted over a frequency-nonselective, slowly fading channel with partial-band interference was analyzed. A procedure referred to as noise-normalization combining was employed by the system receiver to minimize partial-band interference effects. Each hop was assumed to fade independently. The partial-band interference was modeled as a Gaussian process. Both the signal and the partial-band interference were assumed to be affected by the fading channel which

was modeled as Rician. The effect of fading of the partial-band interference on worst-case receiver performance was relatively minor. When there was no signal fading or when the signal fading was Rician, then the counter-intuitive result of poorer receiver performance when the partial-band interference experienced fading was obtained. This effect was most pronounced when the signal did not fade and the partial-band interference experienced Rayleigh fading.

PUBLICATION: Kragh, M. and Robertson, R.C., "The Effect of Rician Fading and Partial-Band Interference on Noise-Normalized, Fast Frequency-Hopped MFSK Receivers," in Proceedings of the IEEE Military Communications Conference, Vol. 1, pp. 182-186, 1993.

DOD KEY TECHNOLOGY AREA: Other.

KEYWORDS: Spread Spectrum, Fast Frequency-hopping, Partial-band Interference.

**EVALUATION OF ANTENNA CHARACTERISTICS BASED ON
AVAILABLE INFORMATION**

**R.C. Robertson, Associate Professor
Department of Electrical and Computer Engineering
Sponsor and Funding: Naval Maritime Intelligence Center**

OBJECTIVE: The purpose of this research program was to develop a set of user friendly mathematical applications capable of computing the radiation pattern and other pertinent antenna parameters of an antenna or antenna system based available information.

SUMMARY: It is important to be able to obtain as specific an idea as possible of the capabilities, limitations, and vulnerabilities of a particular antenna or antenna system. Oftentimes, the only information available is that of a photograph of the system under investigation and the physical size of the system. Generally, this will primarily be information obtained from a photograph and the physical dimensions of the antenna or antenna system; although, the applications are flexible to the extent that they make their computation based on whatever information is available. The mathematical applications are designed to be operated by an engineer familiar with basic antenna types. All mathematical applications are based on existing engineering equations for the antenna type under consideration. A number of applications for various antenna

types have been completed.

PUBLICATIONS: Gerry, D.D. and Robertson, R.C., "Mathcad Computer Applications Predicting Antenna Parameters from Antenna Physical Dimensions and Ground Characteristics," NPS Technical Report NPSEC-93-012, June 1993.

Lundholm, S.E., Robertson, R.C., and Borchardt, R.L., "Predicting Antenna Parameters from Antenna Physical Dimensions," NPS Technical Report NPSEC-93-019, December 1993.

THESES DIRECTED: Gerry, Donald D., LCDR, USN, "Mathcad Computer Applications Predicting Antenna Parameters from Antenna Physical Dimensions and Ground Characteristics," Master's Thesis in Electrical Engineering, June 1993.

Lundholm, Steven E., LT, USN, "Predicting Antenna Parameters from Antenna Physical Dimensions," Master's Thesis in Electrical Engineering, December 1993.

DOD KEY TECHNOLOGY AREA: Sensors.

KEYWORDS: Antenna, Radiation Pattern, Antenna Gain.

COMPILE-TIME SUPPORT FOR THE PROCESSING GRAPH METHODOLOGY
ON THE AN/UYS-2 PARALLEL SIGNAL PROCESSOR

S.B. Shukla, Assistant Professor
Department of Electrical and Computer Engineering
A. Zaky, Assistant Professor
Department of Computer Science
Sponsor and Funding: Naval Sea Systems Command

OBJECTIVE: The goal of this continuing project is to develop a methodology for determining the optimal chains of primitives in processing graph methodology (PGM) applications running on the AN/UYS-2.

SUMMARY: Performance of the AN/UYS-2 can be improved if the primitives of the PGM graph are chained together appropriately. In order to construct the best possible chains automatically instead of manually, a framework, based on a technique called revolving cylinder scheduling, was developed. This technique is based on mapping the graph at compile-time on a cylinder whose curved surface area is determined by the number of processors and graph characteristics such as primitive computation times and data arrival rate. The potential of this technique for chaining as well as for predictable execution was demonstrated by building a simulator for the AN/UYS-2. Work is in progress to determine the feasibility of deploying this technique in the actual AN/UY-2 programming environment. Two theses have been completed and three more are in progress as part of this work.

CONFERENCE PRESENTATION: Shukla, S. B., Little, B., and Zaky, A., "A Compile-Time Technique for Controlling Real-Time Execution of Task-Level Data-Flow Graphs," Inter-

national Conference on Parallel Processing, St. Charles, IL, August 1992. Won the Outstanding Paper Award.

THESES DIRECTED: Little, B.S., USN, "A Technique for Predictable Real-Time Execution in the AN/UYS-2 Parallel Signal Processing Architecture," Master's Thesis in Electrical Engineering, December 1991, (Also filed as a NPS Technical Report, NPSEC-92-002).

Bell, H., LT, USN, "A Compile-Time Approach of Chaining in the AN/UYS-2 Parallel Signal Processor," Master's Thesis in Electrical Engineering, March 1992.

Swank, D., LT, USN, "Large-Grain Data-Flow Graph Restructuring for EMSP Signal Processing Benchmarks on the ECOS Workstation System," Master's Thesis in Electrical Engineering, June 1993.

Cross, D., CAPT, USA, "Usefulness of Compile-Time Restructuring of Large-Grain Data-Flow Programs in Throughput Critical Applications," Master's Thesis in Electrical Engineering, September 1993.

DOD KEY TECHNOLOGY AREA: Computers.

KEYWORDS: Real-time, Signal Processing, Parallel Processing.

**DESIGN AND PERFORMANCE CHARACTERIZATION OF A
MULTIPURPOSE DECENTRALIZED GROUP MEMBERSHIP SERVICE**

S.B. Shukla, Assistant Professor

Department of Electrical and Computer Engineering

Sponsor: Research Initiation Program,

National Science Foundation

Funding: National Science Foundation

OBJECTIVE: The goal of this three-year project is to develop and characterize a multi-purpose and scalable group membership service.

SUMMARY: This project focuses on the structure of a group membership service, a basic building block for group-oriented distributed applications. The objectives of this project are development and performance characterization of a membership service with multiple classes of service. The emphasis is on categorical definition of service classes to support a wide spectrum of applications, adaptive status monitoring to minimize wrongly perceived status changes, a completely decentralized and hierarchial protocol requiring an overhead proportional to the quality of the service rendered, and support of a spectrum of membership semantics in spite of transient network partitioning. Techniques will be developed to support seamless distribution of large groups across a set of heterogeneous networks by exploiting the attributes of local communication environments and using topology-based optimizations. Formal techniques will be used for specification, verification, and implementation of the protocol. A performance metric will be developed for characterization of the perfor-

mance of membership protocols. Performance will be studied with simulations based on stochastic modelling of applications, membership protocols, and underlying networks. The simulations will be built using commercial network engineering tools. The main contributions expected from this research are a single multi-purpose membership protocol instead of the current application-specific variety and quantitative performance characterization which is currently lacking.

THESES DIRECTED: Piers, F., LT, Portuguese Navy, "Design of a Decentralized Asynchronous Membership Protocol and an Implementation of its Communication Layer," Master's Thesis in Electrical Engineering, March 1993.

Pezdirtz, D., LT, USN, "Implementation and Performance Analysis of a Decentralized Group Membership Protocol for Asynchronous Environments," Master's Thesis in Electrical Engineering, December 1993.

DOD KEY TECHNOLOGY AREA: Communications Networking.

KEYWORDS: Reliable, Distributed, Membership.

SONAR SIGNAL MODELING

C.W. Therrien, Professor

Department of Electrical and Computer Engineering

Sponsor and Funding: Naval Undersea Warfare Center
New London

OBJECTIVE: This research involves the development of models for underwater signals received by a passive sonar to support work in classification.

SUMMARY: Research on modeling of acoustic transients and related sonar data was carried out in fiscal year continued in 1993. A comprehensive study to compare ARMA modeling to three other analysis/synthesis methods used in speech modeling was carried out. New work on ocean noise modeling was carried out and a new filtering method for noise removal was developed. Finally, some new methods for data synthesis were developed. Data generated by these methods matches recorded acoustic data in the time and frequency domain. In aural evaluation the data is virtually indistinguishable from physically generated and recorded sonar data.

PUBLICATIONS: Therrien, C.W. and Velasco, C.H., "An Iterative Extension of Prony's Method for ARMA Signal Modeling," NPS Technical Report NPSEC-93-025, 15 September 1993.

Therrien, C.W., Victory, C.W., Pfeifer, G.K., Frack, K.L., and Kjono, O., "Summary Report on Sonar Signal Modeling for FY1993 (U)," NPS Technical Report NPSEC-93-026, 30

October 1993, (SECRET NOFORN Report).

Therrien, C.W., Victory, C.W., and Pfeifer, G.K., "Methods for Modeling Transient Sonar Data (U)," to appear in U.S. Navy Journal of Underwater Acoustics, April 1993, (SECRET NOFORN Report).

CONFERENCE PRESENTATION: Therrien, C. W., "Modeling of Passive Sonar Signals," ONR Full Spectrum Review, State College, PA, September 1993.

THESES DIRECTED: Victory, C.W., LT, USN, "Comparison of Signal Processing Modeling Methods for Passive Sonar Data," Master's Thesis in Electrical Engineering, March 1993.

Velasco, C.H., LT, Columbian Navy, "ARMA Modeling of Signals in the Time Domain," Master's Thesis in Electrical Engineering, December 1992.

OTHER: Therrien, C.W. and Velasco, C.H., "An Iterative Prony Method for ARMA Signal Modeling," IEEE Transactions on Signal Processing, to appear in Spring 1994.

DOD KEY TECHNOLOGY AREA: Sensors.

KEYWORDS: Passive Sonar, ARMA Modeling, Signal Modeling, Acoustic Transients.

MISSILE SIMULATION

H. Titus, Professor

Department of Electrical and Computer Engineering

Sponsor and Funding: U.S. Army Missile &

Space Intelligence Center

OBJECTIVE: The purpose of this effort was to support the Crossbow Committee and several of their intelligence teams. We studied and simulated several Soviet missiles and attempted to develop techniques to counter them.

SUMMARY: We have studied and simulated in considerable detail, the Soviet SA-6, SA-11, and now the follow on system, SA-17x. The SA-6 was used effectively in the 73 War by Egypt. The follow on, the SA-11 is operational in the Soviet Union. The SA-17x is in R&D test. Our task was to know everything possible about the guidance and control of these systems. We have had frequent briefings by CIA, NSA, DIA, MSIC, and others. The simulations have been used to study the missile systems and how to counter them. The purpose of this group is to design and develop several of these systems to be used at appropriate Air Force and Navy facilities. This past year we have

also been studying the SA-15, which is a follow on to the SA-8. However, it is totally new in many aspects; featuring multi-target tracking capability (48 targets) and vertical launch missiles with new ECCM and new EO systems. Export versions of this system are now on sale. In country versions have some significant added capabilities which we are attempting to determine. Numerous meetings and discussions were held. A workshop on missile guidance was given at Huntsville, Alabama. LT Painter's thesis involved a SA-11 Missile Target Simulation. LT Tim Mull developed a simulation and design for the vertical launch phase of these missiles. He did this for the SA-15 and the Sea Sparrow. Work is continuing reviewing threat simulator validation reports.

DOD KEY TECHNOLOGY AREA: Software.

KEYWORDS: Tracking, Missiles, Simulation.

TORPEDO TRACKING

H. Titus, Professor

Department of Electrical and Computer Engineering

Sponsor and Funding: NUWES, Keyport, Washington

OBJECTIVE: Our task was to develop a Kalman filter torpedo tracking program which incorporated the acoustic range data and the torpedo's INS data as well.

SUMMARY: For over a dozen years, we have had thesis students and faculty involved in various torpedo tracking problems as requested by the research arm of the NUWES facility. This past year we investigated the Kalman filter fusing and smoothing of the range acoustic data with an internal INS data. LT Alfaro has done a very good job and they are incorporating his work. The problem was made interesting due to the fact that the INS had very high drift rates, making a problem in aligning accelerometer outputs to the range coordinate system. The observation rates were non-synchronous, and the acoustic data had dropouts, and

discontinuities as the torpedo would pass from one acoustic array to another. LT Wiseman is following on with LT Alfaro's work, incorporating a new maneuver detection algorithm, and now utilizing the accelerometers. The work is classified. Presentations were given at NUWES. LT Turpening continued on with LT Wiseman's work. Professor Art Schoenstadt and Professor Titus are continuing with some software updates. The project was completed in the fall of 1993.

DOD KEY TECHNOLOGY AREA: Software.

KEYWORDS: Tracking, Torpedo, Simulation.

SPACE RESEARCH

H. Titus, Professor

Department of Electrical and Computer Engineering

Sponsor and Funding: SPANAR, NRL, Washington, DC

OBJECTIVE: We wish to locate targets from space platforms and to develop optimal control techniques for attitude control and maneuver of spacecraft.

SUMMARY: Algorithms have been developed to FFT process high PRF pulse Doppler signals and then Kalman filter observable parameters from these coefficients to locate targets of interest. We are presently waiting to test the algorithms on real data. Simulations have been performed on representative signals. Optimal control techniques have been applied in the general attitude control and spacecraft maneuver problem. LTs Mika and Uner did theses on "Fast Envelope Correlation for Passive Ranging" and "Frequency, Amplitude, and Phase Tracking of Non-Sinusoidal Signal in Noise With Extended Kalman Filter," respectively. Cooper's thesis involved a third order optimal con-

trol for spacecraft attitude control. Research briefings were given at NRL. A paper, "Second and Third Order Minimum Time Controllers and Missile Adjoints," was presented by Cooper and Titus at the 34th Midwest Symposium on Circuits and Systems, Monterey, CA, May 14-17, 1991. LTs Mika and Haefner have worked on the analysis of radar emitter signatures via FFT and time domain filtering. LT Sipe continued this effort. LT Merz addressed the problem of placing the sensor on a specific platform and its control problems. Capt Williamson and LT Fallon are extending this work to include RPVs and other sensor platforms. Sensor fusion for locating threat missile and missile radar are being addressed.

DOD KEY TECHNOLOGY AREA: Software.

KEYWORDS: Tracking, Missiles, Simulation.

LORAN-C TRANSMITTER MODELING AND PULSE SHAPING

M. Tummala, Associate Professor

Department of Electrical and Computer Engineering

Sponsor and Funding: Electronics Engineering Center

U.S. Coast Guard, Wildwood, NJ

OBJECTIVE: The goal of this project was to develop signal processing algorithms for modeling of Loran-C transmitters and online shaping of the Loran-C output waveform to meet Coast Guard's specifications. This was a two-year project; the work reported here consists of the concluding part of the two-year effort.

SUMMARY: The Loran-C transmitter is a non-linear and time varying device. We have developed pole-zero models for these transmitters taking the time variations and nonlinearities (as measured from actual experiments) into account. We have used a set of concatenated models to accommodate the nonlinearities and the time variations are tracked using adaptive parameter estimation algorithms. The AN/FPN-42 required 4 poles and 3 zeros while AN/FPN-44A required 6 poles and 3 zeros. In both cases, the waveforms generated by models agreed with the actual transmitter output waveforms under a variety of operating conditions.

The manual methods to control the Loran-C output waveshape is currently used by the Coast Guard, and the Electronics Engineering Center plans to replace the manual control by computer algorithms to achieve better waveshape control and reduced hardware maintenance. We have developed two approaches to accomplish this: a gradient based algorithm and a multichannel parametric algorithm. The multichannel algorithm has yielded

more promising results than the gradient algorithm under a variety of simulated noisy operating conditions. The personnel at the Electronics Engineering Center are now proceeding with the work to test these algorithms on actual transmitters.

PUBLICATIONS: Bruckner, D.C. and Tummala, M., "Nonlinear, Time-Varying Model of the AN/FPN-42 Loran-C Transmitter," in Proceedings of IEEE International Conference on Circuits and Systems, Chicago, IL, May 1993.

Bruckner, D.C., Tummala, M., and Kmiecik, G.A., "A Computer Simulation for Pulse Shape Control of the AN/FPN-42 and AN/FPN-44B Loran-C Transmitters," in Proceedings of the Wild Goose Association Symposium, Santa Barbara, CA, October 1993.

Bruckner, D.C. and Tummala, M., "Automatic Pulse Shaping with the AN/FPN-42 and AN/FPN-44B Loran-C Transmitters," in Proceedings of the Wild Goose Association Symposium, Santa Barbara, CA, October 1993.

THESIS DIRECTED: Wood, John D., LTJG, USCG, "MIMO Recursive Least Squares Control Algorithm for the AN/FPN-44A Loran-C Transmitter," Master's Thesis in Electrical Engineering, September 1993.

DOD KEY TECHNOLOGY AREA: Sensors.

KEYWORDS: Pole-zero Modeling, Waveshape Control, Loran-C Transmitter.

EMP WAVEFORM ANALYSIS FOR AIRCRAFT TESTING

M. Tummala, Associate Professor
Department of Electrical and Computer Engineering
Sponsor and Funding: SY84, Aircraft Division,
Naval Air Warfare Center, Patuxent River, MD

OBJECTIVE: Develop signal processing algorithms for the analysis of electromagnetic pulse (EMP) waveforms measured in aircraft testing and synthesis of the measured waveforms to produce composite test signals for determining aircraft margin of survivability. This is a three-year project; the work reported here consists of the results obtained during the second year of this effort.

SUMMARY: The Naval Air Warfare Center (Code SY84) conducts EMP testing of aircraft. In order to improve their EMP testing techniques, a method for "bounding" the stress waveforms measured inside the aircraft from a series of tests is sought. At each test-point in an aircraft under test, four to eight stress waveforms (signals received at a test-point in response to a simulated EMP pulse) are measured. These signals are currently sampled at 1.3 GHz with the bandwidth of interest being from about 10 kHz to 100 MHz. Three specific tasks were identified to meet their needs: waveform compression for efficient storage, stress waveform bounding using time series modeling approach, and wideband EMP signal analysis to meet their near future bandwidth requirements (10 kHz to 200 MHz). The first task has been completed during AY1992; the second task has been completed during AY1993, and parts of the third task have been undertaken with the rest to be finished in AY1994.

The autoregressive (AR) modeling

approach has been investigated for synthesizing the bounded waveforms. In the first task, the AR models have been successfully used for compressing the EMP waveform data; therefore, we have continued with the AR approach to generate the bounded waveforms as well. We have four stress waveforms per test point, and an AR model has developed for each of those. The poles of the AR models are then combined to synthesize the bounded waveform using two search techniques based on vector quantization and competitive learning neural network algorithms. In the final analysis the bounded waveform produced were highly satisfactory. Nevertheless, the method is prone to yield inconsistent synthesis waveforms when the energy contents of the underlying stress waveforms is significantly disparate. This drawback led us to investigate the feasibility of wideband signal analysis techniques for this work, which is currently in progress.

THESES DIRECTED: Tse, K.B., LT, USN, "AR and ARMA Modeling of EMP Test Data," Master's Thesis in Electrical Engineering, March 1993.

Erdemir, A., LTJG, Turkish Navy, "Data Compression Using Wavelet Transform and Vector Quantization," Master's Thesis in Electrical Engineering, June 1993.

OTHER: Tummala, M. and Tse, K.B., "EMP Data Modeling and Compression using AR models," NPS Report under preparation (sponsor has a draft copy; waiting for comments).

Software developed in Matlab for EMP signal analysis was delivered to Code SY84, NANC; it has been tested by their personnel on their test database.

DOD KEY TECHNOLOGY AREA: Sensors.

KEYWORDS: Data Compression, EMP Waveform, Autoregressive Modeling.

RECURSIVE RAY ACOUSTICS FOR THREE-DIMENSIONAL SPEEDS OF SOUND

L.J. Ziomek, Associate Professor

Department of Electrical and Computer Engineering

Sponsor: Naval Sea Systems Command (NAVSEA)

Funding: NAVSEA

OBJECTIVE: Continue to generalize, test, and evaluate the Recursive Ray Acoustics (RRA) Algorithm. The RRA Algorithm is a simple, fast, and accurate algorithm that can be used to compute the position, angles of propagation, travel time, and path length along a ray path and to draw ray trace plots for speeds of sound that are functions of all three spatial variables. In addition, the RRA Algorithm can calculate the sound-pressure level along individual ray paths for arbitrary, one-dimensional, depth-dependent speeds of sound.

SUMMARY: During fiscal year 1993 (FY 93), computer code was written to give the RRA Algorithm the capability to perform sound-pressure level (SPL) calculations along individual ray paths that are fast, accurate, and valid (i.e., finite) at both turning points and focal points for arbitrary, one-dimensional, depth-dependent speeds of sound. The SPL calculations do not require the use of Airy functions. At each computational step of the algorithm, both ray trace and SPL calculations are performed. Initial testing and validation of the SPL computer code was performed. In addition, the RRA Algorithm was given the capability to find eigenrays.

PUBLICATIONS: Ziomek, L.J. and Polnicky, F.W., "The RRA Algorithm: Recursive Ray Acoustics for Three-Dimensional Speeds of Sound," IEEE Journal of Oceanic Engineering, Vol. 18, pp. 25-30, 1993.

Ziomek, L.J., "Sound-Pressure Level Calculations Using the RRA Algorithm for Depth-Dependent Speeds of Sound Valid at Turning Points and Focal Points," IEEE Journal of Oceanic Engineering, accepted for publication.

CONFERENCE PRESENTATIONS: Ziomek, L.J., "Sound-Pressure Level Calculations Using the RRA Algorithm for Depth-Dependent Speeds of Sound Valid at Turning Points and Focal Points," 125th Meeting of the Acoustical Society of America, 17-21 May 1993, Ottawa, Ontario, Canada, Journal of the Acoustical Society of America, Vol. 93, No. 4, Pt. 2, p. 2425.

Ziomek, L.J., "Sound-Pressure Level Calculations Along Individual Ray Paths Using the RRA Algorithm," International Conference on Theoretical and Computational Acoustics, 5-9 July 1993, Mystic, CT, Session 7.1 Rays and Beams I (invited paper).

OTHER: I presented a half-day tutorial on "Advances in 3D Ray Acoustics" at OCEANS 92, 26-29 October 1992, Newport, RI. The annual OCEANS conference is sponsored by the IEEE Society of Oceanic Engineering.

DOD KEY TECHNOLOGY AREA: Environmental Effects.

KEYWORDS: Three-dimensional Ray Acoustics, Sound-pressure Level Calculations, Underwater Acoustics, Undersea Warfare.

**DEPARTMENT
OF
ELECTRICAL AND COMPUTER
ENGINEERING**

**1993
Faculty Publications
and Presentations**

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Therrien, C.W., "A Framework for the Modeling of Higher-Order Stochastic Processes," 8th Workshop on Image and Multidimensional Signal Processing, Cannes, France, September 1993.

Therrien, C.W. and Hashad, A.I., "The Discrete Wiener Model for Representation of Non-Gaussian Stochastic Processes," 27th Asilomar Conference on Signals, Systems, and Computers, Pacific Grove, CA, November 1993.

Therrien, C.W. and Hashad, A.I., "Applying the Symmetry Properties of Third Order Cumulants in the Identification of Non-Gaussian ARMA Models," IEEE Signal Processing Workshop on Higher Order Statistics, South Lake Tahoe, CA, June 1993.

Tummala, M. and Richter, D.A., "Iterative System Modeling Using Multigrid Techniques," IEEE International Symposium on Circuits and Systems, Chicago, IL, May 1993.

Varnum, K.C.M. and Robertson, R.C., "Error Probabilities of Optical Heterodyne OOK and FSK Communications Systems," IEEE Global Telecommunications Conference, 1993.

Vincent, W.R., "Mitigation of Power-Line Noise," Workshop on Factors Affecting the Performance of Naval Receiving Sites, Naval Postgraduate School, February 1993.

Vincent, W.R., "Examples of Internal Noise Sources at Naval Receiving Sites," Workshop on Factors Affecting the Performance of Naval Receiving Sites, Naval Postgraduate School, February 1993.

Vincent, W.R., "Update on the Use of the Unified Barrier, Filter, Ground Technique to Control EMI/RFI from a PC Uninterruptable Power Supply (UPS)," Workshop on Factors Affecting the Performance of Naval Receiving Sites, Naval Postgraduate School, February 1993.

Vincent, W.R. and Adler, R.W., "The Control of Intra-Site Sources of RFI/EMI at Naval Receiving Sites," NSA 2nd Annual EMC Conference, Ft. Meade, MD, April 1993.

Yildirim, C., Butler, J.T., and Yang, C., "Multi-Valued PLA Minimization by Concurrent Multiple and Mixed Simulated Annealing," 23rd International Symposium on Multiple-Valued Logic, May 1993.

Ziomek, L.J., "Sound-Pressure Level Calculations Along Individual Ray Paths Using the RRA Algorithm," Mathematics and Scientific Computing Colloquium, Department of Mathematics, Naval Postgraduate School, 9 September 1993; and the International Conference on Theoretical and Computational Acoustics, Mystic, CT, Session 7.1 Rays and Beams I (invited paper), 5-9 July 1993.

BOOKS

Lee, C.-H., Digital System Design Using VHDL, CorralTek, Salinas, CA, 1993.

Powers, J.P., Introduction to Fiber Optic Systems, Richard D. Irwin, Inc., and Aksen Associates, 1993. (ISBN 0-256-12996-7)

OTHER PUBLICATIONS

Powers, J.P., (Software Program) "SEMEX -- A Program to Extract Particle Size Information from Scanning Electron Microscope Images," available from NIST (Acquisition No. AD-M000 110; Report number DOD/SW/DK-93/056).

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Borchardt, R.L., Ha, T.T., and Robertson, R.C., "Development of Protocols for Maritime Mobile Communication," NPS Technical Report NPSEC-93-021, November 1993.

Brown, D. W. and Fargues, M. P., "SPC Toolbox: An Interactive Matlab Package for Signal Modeling and Analysis, and Communications," NPS Technical Report, NPSEC-93-017, 15 October 1993.

Dietrich, D.S. and Robertson, R.C., "Predicting Radiation Characteristics from Antenna Physical Dimensions," NPS Technical Report NPSEC-93-009, December 1992 (not published until 1993).

Fargues, M. and Hippenstiel, R., "Investigation of Spectral-Based Techniques for Classification of Wideband Transient Signals," NPS Technical Report NPSEC-93-008, 30 March 1993.

Gerry, D.D. and Robertson, R.C., "Mathcad Computer Applications Predicting Antenna Parameters from Antenna Physical Dimensions and Ground Characteristics," NPS Technical Report NPSEC-93-012, June 1993.

Hippenstiel, R., "Analysis Using Bi-Spectral Related Techniques," NPS Technical Report NPSEC-93-020, 17 November 1993.

Janaswamy, R., "Application of the Measured Equation of Invariance to Wave Propagation Over Irregular, Inhomogeneous Terrain," NPS Technical Report NPSEC-93-018, October 1993.

Lundholm, S.E., Robertson, R.C., and Borchardt, R.L., "Predicting Antenna Parameters from Antenna Physical Dimensions," NPS Technical Report NPSEC-93-019, December 1993.

Mohamed, D.A. and Janaswamy, R., "Design of a Continuous Resistively Loaded Monopole Antenna," NPS Technical Report NPSEC-93-011, May 1993.

Powers, J.P., "Acoustic Propagation Modeling Using MATLAB," NPS Technical Report NPSEC-93-014, 1 September 1993.

Robertson, R.C. and Morgan, M.A., "Ultra-Wide-Band Impulse Antenna Study and Prototype Design," NPS Technical Report NPSEC-93-010, March 1993.

Therrien, C.W., Victory, C.W., Pfeifer, G.K., Frank, K.L., and Kjono, O., "Summary Report on Sonar Signal Modeling for FY 1993 (U)," NPS Technical Report NPS-EC-93-026, October 1993.

Therrien, C.W. and Velasco, C.H., "An Iterative Extension of Prony's Method for ARMA Signal Modeling," NPS Technical Report NPS-EC-93-025, September 1993.

Thiem, K.B. and Janaswamy, R., "Widebanding Techniques for VHF Antennas-II," NPS Technical Report NPSEC-93-007, March 1993.

Vincent, W.R., "Revised Quick-Look Report, NSGD, Rota, Spain, CDAA Site," NSG Technical Report, January 1993.

Vincent, W.R., "Man-Made Radio Noise at NRaD Site F17," NSG Technical Report, July 1993.

Vincent, W.R., "SNEP Team Quick-Look Report at the Rota, Spain, CDAA Site," NSG Technical Report, 10 September 1993.

Vincent, W.R., "Radio Interference at the NPS Beach Receiver Site," NSG Technical Report, November 1993.

Vincent, W.R. and Adler, R.W., "Receiving Conditions at NSGD Shemya," NSG Technical Report, August 1993.

Vincent, W.R. and Adler, R.W., "Field Testing of Engineering Models of High-Dynamic Range Amplifiers," NSG Technical Report, December 1993.

Vincent, W.R., Adler, R.W., and Wadsworth, D.Z., "Quick-Look Report, USA Field Station KOREA and DMZ Det. L," INSCOM Technical Report, May 1993.

Vincent, W.R. and Munsch, G., "Power Line Noise Mitigation Handbook," Southwest Research Institute, January 1993.

**DEPARTMENT
OF
MATHEMATICS**



**Richard H. Franke
Chairman**

DEPARTMENT OF MATHEMATICS

The research program of the Mathematics Department seeks to advance the state of knowledge in the areas important to the Department of the Navy and Department of Defense, such as scientific and parallel computing, weather forecasting, fluid flow, orbital mechanics, and simulation and modeling.

The specific research areas of our faculty and their students are reported in detail, including sponsors, later in this book. Output given in the form of student theses, technical reports, conference presentations, and refereed journal articles.

SCIENCE COMPUTATION

The area of scientific computation includes both numerical (on serial and parallel computers), and analytical (symbolic) solutions to a variety of problems of interest to the Department of the Navy and Department of Defense. Research has been conducted by Professors Danielson, Neta and several students to develop parallel versions of the satellite motion models in current use by NAVSPACECOM and AFSPACECOM. The algorithms were tested on the INTEL hypercube. They are also developing such algorithms to run on a cluster of networked workstations running Parallel Virtual Machine (PVM) software.

Professors Gragg and Borges continued their work on stable parallel algorithms for eigenproblems and singular value problems. Professor Gragg is also working on parallel and block algorithms for updating QRP' factorizations.

Professor Neta continued his work with Professor R.T. Williams of Meteorology on the development of schemes for weather prediction using parallel computers.

On scientific, non-parallel computing, Professor Franke continues his work on scattered data approximation especially with application to meteorological data.

Professor Borges is continuing his work on quasi-Gaussian quadratures and their application to solving eigenproblems on serial and parallel computers. He is also working on the numerical reconstruction of stochastic differential operators.

Professor Hanson is working with multigrid and multilevel methods. Such methods can be applied to a variety of problems. He joins Professor Rasmussen to apply multilevel methods to optimization and network flow problems. In addition, he is developing multilevel methods of image reconstruction from projections.

Professors Canright and Scandrett are continuing their work on the application of the T-matrix approach to analyze an array of radiating transducers. This work is applicable in Undersea Warfare.

Professor Canright is also working on welding problems as applied to the construction of ships and submarines. Professor Danielson is contributing to the

design of ship structures in his work with Professor Fakhroo.

Professor Frenzen is continuing his work in asymptotic analysis. Asymptotic Expansions have been applied to problems in nonlinear wave propagation and mathematical physics.

SIMULATION AND MODELING

Professors Barr and Weir are continuing their work on combat models for the U.S. Army TRADOC Analysis Center. This work is aimed at using high level measures of combat effectiveness in training applications.

Professors Mansager and Meta are continuing their work on Audio detection algorithms, and modelling of the TUG-V (Tactical Unmanned Ground Vehicle). Professor Mansager is also working on modelling the JAVELIN.

Professors Barr and Meta are editors of the special issue of International Journal Mathematical and Computer Modeling dedicated to combat modelling.

DISCRETE MATHEMATICS

Professor Fredricksen continues his research in communication protocols. The work is theoretical at present but has promise for practical application in certain broadcast communications scenarios. His work on covers in deBruijn graphs has application to an error correction system for stream ciphers which is analogous to the block ciphers of classical coding systems. Single error correcting codes in this design occur when certain vertices in the appropriate graph preclude others from appearing in the code. The topology of the underlying graph is different for the stream cipher problem.

Professor Guillermo Owen continues his research into game theory. He is working on multilinear extensions of games as applied in economics, management and political sciences.

Professor Hanson is developing a discrete Fourier transform tutorial with Professor Briggs of Colorado.

**FURTHER APPLICATIONS OF QUASI-GAUSSIAN
QUADRATURE AND NUMERICAL RECONSTRUCTION
OF DIFFERENTIAL OPERATORS**

**C.F. Borges, Assistant Professor
Department of Mathematics**

Sponsor and Funding: Naval Postgraduate School

OBJECTIVE: Continued research into applications of the quasi-Gaussian quadrature and numerical reconstruction of differential operators. Other goals included the further development of the parallel tridiagonal divide and conquer algorithm for solving large eigenproblems.

SUMMARY: Work on applications of quasi-Gaussian quadrature this year has yielded some promising results in condition estimation and on modified shifting strategies for the QR algorithm for solving eigenproblems. I have begun initial investigations and have constructed some test codes for trying various schemes for using the quasi-orthogonal polynomials developed earlier in this research program in the two applications mentioned above. Initial results are promising but not yet conclusive and more experiments are required before proceeding with a mathematical analysis of the results.

Work on the numerical reconstruction of stochastic differential operators has resulted in the publication of two papers and the solicitation of another for the Journal of Mathematical Systems, Estimation and Control. This work has generated some interest among some of the premiere researchers in the field of stochastic control and digital image processing. The work did not progress as quickly as hoped since I was not able to take a trip to Italy to spend time with my collaborator this year and he was unable to visit here. We hope to spend more time on

it during the current year. The focus of the algorithms is being brought more into line with the widely known theoretical work of Gelfand and Levitan from the early 1960's. We hope to eventually develop a complete numerical approach to this important problem from control theory and then continue to extend it to the stochastic case which should be of considerable interest to the Department of the Navy.

Finally, a substantial effort was directed to the study and development of the parallel divide and conquer algorithm for generalized symmetric eigenproblems. This work has resulted in the publication of two papers with W.B. Gragg and a conference presentation. This work is already widely known and respected. We have been pursuing other aspects of the algorithm this past year including an investigation of methods for implementing it in a distributed computing environment and the refinement of deflation techniques that are used to simplify the problem. We have several new results and I believe that these will lead to further publications and possibly to external funding for this research.

PUBLICATIONS: Borges, C.F. and Frezza, R., "On Model Identification of Gaussian Reciprocal Processes from the Eigenstructure of Their Covariances," in Computation and Control III: in Proceedings of the Third Bozeman Conference, J. Lund and K. Bowers, eds., Progress in Systems and Control Theory, Birkhauser,

pp.63-72, 1993.

Borges, C.F. and Gragg, W.B., "A Parallel Divide and Conquer Algorithm for the Generalized Real Symmetric Definite Tridiagonal Eigenproblem," in Numerical Linear Algebra and Scientific Computing, L. Reichel, A. Ruttan, and R.S. Varga, eds., de Gruyter, Berlin, pp. 11-29, 1993.

Borges, C.F., "On a Class of Gauss-like Quadrature Rules," to appear in Numerische Mathematik.

Borges, C.F., Frezza, R., and Gragg, W.B., "Some Inverse Eigenproblems for Jacobi and Arrow Matrices," to appear in Journal of Numerical Linear Algebra Applications.

CONFERENCE PRESENTATIONS: Borges, C.F., "A Parallel Divide and Conquer Algorithm for the Generalized Real Symmetric Definite Tridiagonal Eigenproblem," Third SIAM Conference on Linear Algebra, Signals, Systems, and Control, University of Washington, Seattle, 19 August 1993.

OTHER: Borges, C.F., "Numerical Determination of Tristimulus Values,"

submitted to Journal of Optical Society of American A., (under revision).

Borges, C.F. and Frezza, R., "On Model Identification of Gaussian Reciprocal Processes from the Eigenstructure of their Covariances," Journal of Mathematical Systems, Estimation and Control, (under revision).

The investigator is preparing the Color Toolbox, a set of Matlab programs and data sets for use in the study of human color perception and for applications of color in scientific visualization and image processing. The investigator is also continuing the development of parallel software for solving eigenproblems using the divide and conquer algorithm.

DOD KEY TECHNOLOGY AREA: Other.

KEYWORDS: Inverse Problems, Color Perception, Eigenproblems, Reciprocal Stochastic Processes.

ANALYSIS OF THERMOCAPILLARY CONVECTION IN WELDING

D.R. Canright, Associate Professor

Department of Mathematics

Sponsor and Funding: Office of Naval Research

OBJECTIVE: The goal of this project is to determine the scaling and structure of the "cold-corner singularity" in thermocapillary flow in weld pools. This is a continuing project.

SUMMARY: Recent work in modeling thermocapillary convection in materials processing, for example in the pool of liquid metal formed during welding, shows a region of rapid flow and intense heat transfer, concentrated in the "cold corner" region. A theoretical understanding of this region, currently lacking, is essential for accurate numerical models. The objective of this study is to analyze the coupled thermal and flow fields in this important region, including the dependence on the governing parameters. The results should be useful in developing more complete numerical models of the welding process, to understand how to make welds more reliable.

In 1993, the model problem was simulated numerically using two different methods. The numerical results from a large number of computations over a variety of parameter pairs were compared with the scaling analysis previously developed. These results validated the asymptotic behaviors predicted by the scaling for the four asymptotic regimes, and also showed the details

of the transitions between regimes. One surprising result is that no thermal boundary layer was formed, even for very vigorous convection.

PUBLICATION: Canright, D., "Analysis of Thermocapillary Convection in Welding," NPS Technical Report NPS-MA-93-011, March 1993.

CONFERENCE PRESENTATION: Canright, D., "Thermocapillary Convection Near a Cold Wall," 45th Annual Meeting of the Division of Fluid Dynamics of the American Physical Society, Tallahassee, FL, 22-24 November 1992. (Abstract published in Bulletin of the American Physical Society 37, No. 10 (1992): 1785-1786.)

THESIS DIRECTED: Huber, Michael, "An Investigation of Low Marangoni Number Fluid Flow in a Cold Corner," Master's Thesis in Applied Mathematics, June 1993.

OTHER: Two journal articles were prepared: one will appear in Physics of Fluids; the other (with M. Huber) is submitted to Journal of Heat Transfer.

DOD KEY TECHNOLOGY AREA: Materials and Processes.

KEYWORDS: Thermocapillary, Solidification, Welding, Crystal Growth, Convection, Marangoni.

**MAXIMUM STRESSES IN CLAMPED RECTANGULAR PLATES
UNDER AXIAL LOAD AND LATERAL PRESSURE**

D.A. Danielson, Professor

F. Fakhroo, Visiting Assistant Professor

Department of Mathematics

Sponsor and Funding: David Taylor Naval Ship R&D Center

OBJECTIVE: Improve structural design of ships.

SUMMARY: The goal of this work is to obtain the maximum stresses in rectangular plates subjected to axial load and lateral pressure. The stresses will be calculated using a computer code developed by Professor Charles Steele and his colleagues at Stanford University. Implications will be made for the current Navy design for ship plating.

PUBLICATIONS: Danielson, D.A., Cricelli, A.S., Frenzen, C.L., and Vasudevan, N., "Buckling of

Stiffened Plates Under Axial Compression and Lateral Pressure," International Journal of Solid Structures, Vol. 30, No. 4, pp. 545-551, 1993.

Hodges, D.H., Atilgan, A.R., and Danielson, D.A., "A Geometrically Nonlinear Theory of Elastic Plates," Journal of Applied Mechanics, Vol. 60, pp. 109-116, March 1993.

DOD KEY TECHNOLOGY AREA: Computers, Other.

KEYWORDS: Plates, Stresses, Ship Structures.

NATURAL FREQUENCIES OF VIBRATING BEAMS

D.A. Danielson, Professor

Department of Mathematics

D. Brown, Research Assistant Professor

Department of Physics

Sponsor and Funding: Naval Postgraduate School

OBJECTIVE: Develop formulas for prediction elastic module of hydrophone materials.

SUMMARY: Literature on the dynamic resonance method for measuring the elastic module of solids was reviewed. Formulas were extended to correct for the added mass and stiffness of the wires used in experiments being conducted at the Naval Postgraduate School Acoustics Laboratory.

OTHER: The investigators and LT Mick Meissel are preparing a paper for submission to the Journal of the Acoustical Society of America, completion expected in 1994.

DOD KEY TECHNOLOGY AREA: Materials and Processes, Other.

KEYWORDS: Acoustics, Hydrophones, Beams.

ORBIT PREDICTION ON PARALLEL COMPUTERS

D.A. Danielson, Professor

B. Neta, Professor

Department of Mathematics

Sponsor and Funding: NAVSPACECOM (formerly NAVSPASUR)

OBJECTIVE: To investigate the feasibility of using parallel computers to efficiently predict orbits of objects and to develop parallel versions for such prediction models. To document and improve the orbit prediction via Semianalytic Satellite Theory.

SUMMARY: Parallel versions of PPT2, the analytic orbit propagator currently in use by NAVSPASUR (now NAVSPACECOM) were developed and tested. A parallel versions of SGP and SGP4/SDP4 (in use by USSPACECOM) were developed and tested. The above models were also running on a network of workstations using PVM (Parallel Virtual Machine, Software developed by Oak Ridge National Lab). Semianalytic satellite theory was documented to facilitate parallelization in the future. We are also testing a version of the code on a unix workstation to compare the accuracy and timing.

PUBLICATIONS: Phipps, W.E., Neta, B., and Danielson, D.A., "Parallelization of the Naval Space Surveillance Satellite Motion Model," Journal of Astronautical Sciences, Vol. 41 pp. 207-216, 1993.

Phipps, W.E., Neta, B., and Danielson, D.A., "Parallelization of the Naval Space Surveillance Satellite Motion Model," in Proceedings of the 1993 Space Surveillance Workshop, M.I.T. Lincoln Lab, Lexington, MA, 30 March -1 April 1993, R.W. Miller, R. Sridharan, Eds., Vol. 2, pp. 71-79, 1993.

Neta, B., "Parallel Solution of Initial Value Problem," in Proceedings of the Fourth International Colloquium on Differential Equations, Plovdiv, Bulgaria, 18-23 August 1993.

Danielson, D.A., "Semianalytic Satellite Theory: Mathematical Algorithms," in Proceedings of 1993 Space Surveillance Workshop, M.I.T. Lincoln Lab, Lexington, MA, 30 March -1 April, Vol. 2, pp. 61-70, 1993.

Danielson, D.A., "Semianalytic Satellite Theory: Second Order Expansions in the true Longitude L," in Proceeding of the AAS/AIAA Astrodynamics Conference, Victoria, BC, AAS 93-720, 16-19 August 1993.

CONFERENCE PRESENTATIONS: Danielson, D.A. and Neta, B., "Orbit Determination on Parallel Computers," Space Systems AE3815, NPS, 12 October 1993.

Neta, B., "Parallel ODE Solvers," Numerisk Institut, Danmarks Teknisk Højskole, Lyngby, Denmark, 10 August 1993.

Neta, B., "Parallel Solution of Initial Value Problem," in Proceedings of the Fourth International Colloquium on Differential Equations, Plovdiv, Bulgaria, 18-23 August 1993.

Neta, B., "Orbit Prediction on Parallel Computers (MIND Machines and PVM)," Parallel Processing Forum, Phillips Lab./VTA, Kirtland AFB, NM, 8 December 1993.

Danielson, D.A., "Semianalytic Satellite Theory: Mathematical Algorithms," 1993 Space Surveillance Workshop, M.I.T. Lincoln Lab, Lexington, MA, 1 April 1993.

Danielson, D.A., "Semianalytic Satellite Theory: Second Order Expansions in the true Longitude L," AAS/AIAA Astrodynamics Conference, Victoria, BC, 17 August 1993.

Danielson, D.A., "Semianalytic Satellite Theory: Mathematical Algorithms," Stanford University seminar, Palo Alto, CA, 14 October 1993.

THESES DIRECTED: Ostrom, Sara, LT, USN, "Parallelization of the Air Force Space Command Satellite Model," March 93.

Dyar, Walter, Major, USMC, "Comparison of Orbit Propagators in the Research and Development Goddard Trajectory Determination System (R & D GTDS)," September 1993.

Brewer, Susan, LT, USN, "Air Force Space Command Satellite Orbit Predictor Using Parallel Virtual Machines," December 1993.

Stone, Leon, LT, USN, "Parallel Processing of Navy Specific Applications Using a Workstation Cluster," December 1993.

OTHER: The investigators are preparing a book-length document of the mathematical algorithms of Semianalytic Satellite Theory. Completion expected in 1994.

DOD KEY TECHNOLOGY AREA:
Computers, Other.

KEYWORDS: Orbit Prediction, Parallel Solution, Semianalytic Satellite Theory, Parallel Virtual Machines.

APPROXIMATION OF SURFACES FROM SCATTERED DATA

R. Franke, Chairman and Professor

Department of Mathematics

Sponsor and Funding: None

OBJECTIVE: The goal of this project is to investigate the use of radial basis functions to approximate surfaces from scattered data. The data presumably is derived from measurements with error, and are sufficiently numerous that a good approximation can be obtained with many fewer basis functions than there are data points.

SUMMARY: The basis functions chosen are multiquadric functions, with the approximation being a linear combination of multiquadrics at scattered nodes (called knots, here) plus a constant term. The coefficients in the approximation are determined by minimizing the sum of the squares of the errors at the data points. The coefficients are constrained so that constant precision is assured. Three algorithms were developed: (1) A greedy algorithm that used a given constant value for the multiquadric parameter and a subset of the data points as knots; (2) A variable knot, variable multiquadric parameter algorithm with those parameters being determined by nonlinear optimization; and (3) A version of (2) where the multiquadric parameter is allowed to be different at different knots.

While the greed algorithm is relatively fast, (2) results in approximations with error results in approximations with error reduced by a factor of (3) results in another reduction in error by a factor of 3 to 10 more.

PUBLICATION: Franke, R., Hagen, H., and Nielson, G.M., "Least Squares Surface Approximation to Scattered Data Using Multiquadric Functions," NPS Technical Report NPS-MA-93-008, (revised version to appear in Advances in Computational Mathematics).

CONFERENCE PRESENTATIONS: Franke, R., "Least Squares Surface Approximation Using Multiquadric Functions," Topics in CAGD '93, Wolfenbuettel, Germany, June 1993.

Franke, R., "Least Squares Surface Approximation Using Multiquadric Functions," Geometric Modelling, Dagstuhl Seminars, Schloss Dagstuhl, Germany, July 1993.

DOD KEY TECHNOLOGY AREA: Other.

KEYWORDS: Scattered Data, Surfaces, Multiquadrics, Least Squares, Variable Knots.

COUNTING SHIFT REGISTER CYCLES

H. Fredricksen, Professor
Department of Mathematics
Sponsor and Funding: Unfunded

OBJECTIVE: To determine the number of shift register factors that produce one cycle which contains all of the binary n -tuples of weight t or less.

SUMMARY: We decomposed all of the binary n -tuples into cycles of vectors all of the same density/weight by the pure cycling algorithm. We then modified the shift register feedback function to join the cycles of weight $\leq t$ together. The BEST theorem was then employed to count the number of ways in which this can

be done.

PUBLICATIONS: Fredricksen, H., "The Number of Non-linear Shift Registers that Produce all Vectors of Weight $\leq t$ ", IEEE Transactions on Information Theory, Nov 1993.

DOD KEY TECHNOLOGY AREA: Computers.

KEYWORDS: BEST Theorem, Binary Sequence, deBruijn Graph, Cycle Joining, Shift Registers, Spanning Tree, Truth Table.

COMBINING SEQUENCES FOR THE DE BRUIJN PROPERTY

H. Fredricksen, Professor
Department of Mathematics
Sponsor and Funding: Unfunded

OBJECTIVE: To generalize the notion of deBruijn sequences. Continues as a DFR project.

SUMMARY: While deBruijn sequences have many applications it has been verified that additional sequences could be produced if the n bits of interest need not be consecutive. Some sequences have been found with this new property. When the combs used have only one stretch of contiguous bits of length bigger than one, we have shown that the sequences

follow a new deBruijn graph. We have found properties of these sequences that may have great cryptographic significance.

THESIS DIRECTED: (Ph.D. student is being directed on this topic).

DOD KEY TECHNOLOGY AREA: Communications Networking.

KEYWORDS: deBruijn Sequences, Shift and Add Property, Values, deBruijn Graph.

DRAWING DEBRUIJN GRAPHS
H. Fredricksen, Professor
Department of Mathematics
Sponsor and Funding: Unfunded

OBJECTIVE: The deBruijn graph of span larger than $5/6$ is extremely unwieldy to draw. For this reason, it is difficult to determine the properties of the graph, such as the cycle structure. Redrawing the graph hopefully will enable us to better understand it's properties.
(continues - unfunded)

SUMMARY: Several different approaches to configure the vertices of the deBruijn graph in different ways have been completed. The applications to more efficient layouts of circuits in silicon has been studied and improvements are being sought.

PUBLICATIONS: Fredricksen, H., "A New Look at the deBruijn Graph," Discrete Applied Math, Vol. 37, No.38, pp. 193-203, 1992.

THESIS DIRECTED: Thesis student anticipated.

OTHER: Another paper in progress on this topic.

DOD KEY TECHNOLOGY AREA:
Communications Networking.

KEYWORDS: DeBruijn Graph, Cycle Adjacency Array, Decycling Sets.

NONLINEAR MODE COUPLING IN FREE ELECTRON LASERS

C.L. Frenzen, Associate Professor

Department of Mathematics

Sponsor and Funding: Naval Postgraduate School

OBJECTIVE: The goal of this project was to develop a two mode model of the optical field in a free electron laser in which the optical modes are coupled by the free electrons in the laser.

SUMMARY: The optical field in a free electron laser can sometimes develop sidebands and exhibit very complex behavior. A two optical mode model of the optical field in a free electron laser is developed. In this model the optical modes are coupled by the free electrons in the laser. The equations of motion are formulated as a first order system of ordinary differential equations with

slowly varying coefficients. The derivation involves nondimensionalization of the problem and isolation of appropriate time scales. A regime of particular interest is that of sustained resonance in the two-mode model. The model can be used to study the long time stability of the optical wave.

PUBLICATION: Frenzen, C.L., "Nonlinear Mode Coupling in Free Electron Lasers," NPS Technical Report NPS-MA-93-012, March 1993.

DOD KEY TECHNOLOGY AREA: Other.

KEYWORDS: Free Electron Laser.

**STABLE PARALLEL DIVIDE AND CONQUER ALGORITHMS
FOR EIGENPROBLEMS AND SINGULAR VALUE PROBLEMS (1992)**

**W.B. Gragg, Professor
C.F. Borges, Assistant Professor
Department of Mathematics
Sponsor and Funding: ETH Zuerich**

OBJECTIVE: To produce and analyze high quality parallel numerical software for real symmetric tridiagonal eigenproblems and bidiagonal singular value problems, based on ideas of Gragg, Thornton and Warner. To understand the difficulties of obtaining numerically orthogonal eigenvectors and to construct provable rigorous codes for solving these problems. To implement the algorithms on distributed networks of work stations.

SUMMARY: Gragg earlier developed matlab codes for the tridiagonal problem based on the GTW variant of the algorithm of Cuppen, Dongarra, Sorensen and Tang. During the 1992 fiscal year he substantially improved an error analysis of the classical algorithm by Barlow. He also learned of a scheme of Gu and Eisenstat, of Yale, for stabilizing the classical algorithm, adapted it to the GTW scheme, and modified his matlab codes. We now obtain provable numerically orthonormal eigenvectors in working precision. Thus we can handle gigantic problems safely. After Gragg's return to Monterey, during the current fiscal year, this work was written up and published with Borges. This is the first published paper which shows that divide and conquer algorithms for eigenproblems, decidedly nontrivial computational problems, are rigorously feasible for parallel computation. Borges is adapting the matlab codes to run on distributed networks of work stations, not an easy task due to the intricacies of the algorithm. However, the

Gu-Eisenstat approach makes the algorithm "less parallel." We feel that the ultimate code of this type will avoid it in favor of the Sorensen-Tang approach using sep (simulated extended precision) arithmetic. During the 1993 fiscal year Gragg completed his matlab codes for sep arithmetic by building an algorithm to do addition of double length numbers always with high relative precision. These codes need to be "maxed". They will then be of good use to the scientific community, as matlab currently has no efficient way to monitor the propagation of rounding errors. Borges and a graduate student are working on this task.

PUBLICATIONS: Gragg, W.B. and Demmel, J.W., "On Computing Accurate Singular Values and Eigenvalues of Matrices with Acyclic Graphs," Linear Algebra and its Applications, Vol. 185, pp. 203-218, 1993.

Gragg, W.B. and Borg, C.F., "A Parallel Divide and Conquer Algorithm for the Generalized Real Symmetric Definite Eigenproblem," in Numerical Linear Algebra and Scientific Computing, L. Reichel, A. Ruttan and R.S. Varga, eds., de Gruyter, Berlin, pp. 10-28, 1993.

CONFERENCE PRESENTATIONS: Gragg, W.B., "A Parallel Divide and Conquer Algorithm for the Generalized Real Symmetric Definite Tridiagonal Eigenproblem," Navy Research and Development Conference, NRD, San Diego, CA, 14 April 1993.

Gragg, W.B. and Borges, C.F., "A Parallel Divide and Conquer Algorithm for the Generalized Real Symmetric Definite Tridiagonal Eigenproblem," invited, 882nd Meeting of the American Mathematical Society, Northern Illinois University, DeKalb, Illinois, 24 May 1993.

OTHER: Gragg, W.B., Borges, C.F., and Frezza, R., "Some Inverse Eigenproblems for Jacobi and Arrow Matrices," Journal of Numerical Linear Algebra and Applications, forthcoming.

Gragg, W.B. and Borges, C.F., "Divide and Conquer for Generalized Real Symmetric Definite Tridiagonal Eigenproblems," in Proceedings of the Shanghai International Conference on Numerical Linear Algebra and Applications, Shanghai, October 1992, forthcoming.

Gragg, W.B., "Divide and Conquer Algorithms for Structured Eigenvalue

Problems," Department of Mathematical Sciences, Simon Fraser University, Vancouver, Canada, 22 April 1993.

Gragg, W.B., "A Parallel Divide and Conquer Algorithm for the Generalized Real Symmetric Definite Tridiagonal Eigenproblem," Department of Computer Science, University of Utah, Salt Lake City, 20 May 1993.

Gragg, W.B., "Divide and Conquer Algorithms for Structured Eigenvalue Problems," Department of Mathematics, University of Bremen, Germany, 24 August 1993.

DOD KEY TECHNOLOGY AREA: Other.

KEYWORDS: Distributed Computing, Hermitian Eigenproblems, Singular Value Problems.

TOEPLITZ AND UNITARY HESSENBERG MATRICES
WITH APPLICATIONS TO SIGNAL PROCESSING

W.B. Gragg, Professor
Department of Mathematics
Sponsor and Funding: None

OBJECTIVE: To pursue the algorithmic structure inherent in such special matrices, and the connections between them, in order to obtain numerically stable and fast algorithms for applications involving them. To relate them with special dynamical systems and to pursue the analogies between them and the related classes of Hankel and real symmetric tridiagonal matrices.

SUMMARY: My first paper on this area was published, in Russian, in 1982. The English version has been circulated privately and, together with other work by Ammar, Gragg and Reichel (AGR), has stimulated interest in this area. It was requested that the English version be published and this occurred in 1993. Five further papers were also published and two talks were given. There are formal connections among these areas and the KdV and modified KdV PDEs. These are basic for inverse scattering. These connections need to be developed in more detail as they seem to imply that certain "big" results about the connections between the two PDEs follow from very classical results on orthogonal polynomials. The algorithms of this area need to be disseminated to engineers, who are currently using much less attractive schemes. Based on a four page proceedings paper by AGR in 1986 Angelika Bunse-Gerstner of Bremen and her students and collaborators have taken the unitary Hessenberg eigensolutions further. In fact she was recently invited to become a member of the organizing committee of the prestigious Householder Symposia

on Numerical Linear Algebra primarily on the basis of this work. The eigenvalues provide "directions of arrival." More work needs to be done on the numerical stability. We recently showed (unpublished) that the eigenvalues are insensitive to changes in the data, a certain encoding of the Schur parameters. We must now organize the algorithms so they reflect this inherent stability of the problem. This no one has done, and it is the most important practical problem!

PUBLICATIONS: Gragg, W.B., Ammar, G.S., and Reichel, L., "Downdating of Szego Polynomials and Data Fitting Algorithms," Linear Algebra and its Applications, Vol. 172, pp. 315-336, 1992.

Gragg, W.B., Ammar, G.S., and Reichel, L., "An Analogue for Szego Polynomials of the Clenshaw Algorithm," Journal of Computational and Applied Mathematics, Vol. 46, pp. 211-216, 1993.

Gragg, W.B., "Positive Definite Toeplitz Matrices, the Arnoldi Process for Isometric Operators, and Gaussian Quadrature on the Unit Circle," Journal of Computational and Applied Mathematics, Vol. 46, pp. 183-198, 1993.

Gragg, W.B., Faybusovich, L., and Ammar, G.S., "Inverse Problems for Orthogonal Matrices, Toda Flows, and Signal Processing," in Proceedings of the 31st Conference on Decision and Control, IEEE, New York, pp. 1488-1493, 1992.

Gragg, W.B., Ammar, G.S., and Reichel, L., "Direct and Inverse Unitary Eigenproblems in Signal Processing: An Overview," in Linear Algebra for Large Scale and Real Time Applications, M.S. Moonen, G.H. Golub and B.L.R. De Moor, Eds. NATO ASI Series E, Volume 232, Kluwer Academic Publishers, Dordrecht, The Netherlands, pp. 341-343, 1993.

CONFERENCE PRESENTATIONS: Gragg, W.B., Ammar, G.S., and Faybusovich, L., "Inverse Problems for Orthogonal Matrices, Toda Flows, and Signal Processing," 31st IEEE Conference on Decision and Control, Tucson, Arizona, 17 December 1992.

OTHER: Gragg, W.B. and Ammar, G.S.,

"Schur Flows for Orthogonal Hessenberg Matrices," in Proceedings of Fields Institute Workshop on Hamiltonian and Gradient Flows, Algorithms, and Control, Waterloo, Canada, March 1992, forthcoming.

Gragg, W.B., "Going Around on Circles," Department of Mathematics, University of Bremen, Germany, 26 August 1993.

DOD KEY TECHNOLOGY AREA: Other.

KEYWORDS: Toeplitz Matrices, Signal Processing.

**PARALLEL AND BLOCK ALGORITHMS FOR COMPUTING
AND UPDATING QRP' FACTORIZATIONS**

W.B. Gragg, Professor

J.R. Thornton, Assistant Professor

Department of Mathematics

Sponsor: Office of Naval Research

Funding: Naval Postgraduate School

OBJECTIVE: To create high quality parallel software for updating and downdating QRP' factorizations, which can be used for solving problems of real time signal processing.

SUMMARY: The most robust techniques for dealing with linear least squares problems use singular value decompositions (svds) of rectangular matrices. The svd is so important that, I understand, the Navy has supported the construction of a special purpose machine for it. The svd is a special eigenvalue problem. As such it cannot be updated inexpensively when new data enters the problem (or old data leaves). The QRP' factorization is a surprisingly simple extension of the svd idea which does not suffer from this defect. And, also surprisingly, the idea is quite new. There is much current activity in this area of computational linear algebra. In fact, I understand that General Electric is building a special purpose machine for QRP' factorizations. A related subproblem is that of condition estimation. With

Stewart we gave the first algorithm for this problem in 1976. There are now many such competing algorithms. For this project we wrote about a dozen matlab codes for the various kinds of updates and were in the process of scrutinizing them to make them as reliable as possible. Thornton was to parallelize these codes but his employment was terminated by NPS. Also, although the project was originally supported by NPS for two years, the second year of support was withdrawn with no notice. Thus it will not be completed. I have given my codes to Monique Fargues of the ECE department. She also has great interest in this area and, I understand, has graduate students who work with these algorithms.

OTHER: A package of (experimental, but rather reliable) matlab codes for condition estimation and for updating and downdating QRP' factorizations.

DOD KEY TECHNOLOGY AREA: Other.

KEYWORDS: Recursive Least Squares.

**MULTILEVEL APPROACHES TO OPTIMIZATION
AND DISCRETE OPTIMIZATION PROBLEMS**

V.E. Henson, Assistant Professor

C.W. Rasmussen, Assistant Professor

Department of Mathematics

Sponsor: Research Initiation Program

Funding: Naval Postgraduate School

OBJECTIVE: To devise techniques by which multilevel methodology can be applied to computationally slow optimization and discrete optimization problems, and to develop an underlying theory for these applications.

SUMMARY: Many problems in optimization and discrete optimization can be solved only by computationally slow, "grinding" processes. A similar computational "stalling" characterizes many of the classical iterative methods for solving partial differential equations (PDEs). Over the past fifteen to twenty years multigrid methods have been developed to solve these PDE problems, and have been tremendously successful. This research is intended to investigate the possibility that multigrid-like algorithms, called multilevel methods, can be developed for the computationally slow optimization and discrete optimization problems. The focus has been on network flow problems, with emphasis on the long transportation problem.

This project was funded for fiscal 1993, following up on unfunded work that was commenced in 1992. A joint paper (by Prof. Henson, with LT Kevin J. Cavanaugh, USCG) was presented at a major conference and appears in the published proceedings of that conference. A Master's thesis (the second in a sequence) was produced, jointly directed by Professors Henson

and Rasmussen. A third Master's thesis resulting from this project is currently being written, and will be completed in Spring quarter, 1994.

PUBLICATIONS: Cavanaugh, K.J. and Henson, V.E., "A Multilevel Cost-Space Approach to Solving the Balanced Long Transportation Problem," in Proceedings of the 6th Copper Mountain Conference on Multigrid Method, NASA Conference Publication Number 3224, 1993.

CONFERENCE PRESENTATIONS: Cavanaugh, K.J. and Henson, V.E., "A Multilevel Cost-Space Approach to Solving the Balanced Long Transportation Problem," 6th Copper Mountain Conference on Multigrid Methods, Copper Mtn, CO, 7 April 1993.

THESIS DIRECTED: Cornett, Annette P., LT, USN, "A Multigrid Approach to Solving the Long Transportation Problem on a Regular Grid in Cost Space," Master's Thesis, June 1993.

OTHER: This research is to be the topic of a Master's thesis now being written by LT Javier Nieto (Spain), to be jointly directed by Professors Gordon Bradley and Van Henson, with Professor Craig Rasmussen serving as second reader.

DOD KEY TECHNOLOGY AREA: Other.

KEYWORDS: Multigrid, PDEs, Image Reconstruction.

MULTIGRID, MULTILEVEL, AND MULTILEVEL PROJECTION METHODS

V.E. Henson, Assistant Professor

Department of Mathematics

Sponsor: Research Initiation Program

Funding: Naval Postgraduate School

OBJECTIVE: To formulate theoretical foundations of the multigrid, multilevel, and multilevel projection method (PML), and apply them to several problems, specifically to the image reconstruction problem and to the solution of certain nonlinear PDEs.

SUMMARY: This work is the unfunded continuation of projects funded in 1990, 1991, and 1992 by the Naval Postgraduate School Research Council. Multigrid and multilevel methods are numerical computation methods that take advantage of all of the scales of a problem in order to accelerate the convergence to the solution. Design and implementation of the methods, however, is not simple, and many workers have resisted using them because of their complexity. Recently a new approach called multilevel projection was formulated by Stephen F. McCormick which greatly simplifies the design and implementation of multilevel methods. This project investigates the theoretical foundation and the application of these methods to several types of problems, including solution and grid refinement methods for PDEs, specifically certain semilinear elliptic equations that arise in non-Newtonian fluid flow, and multilevel methods for image reconstruction (the Radon Transform problem).

Output from this research in 1993 included one published paper and one conference presentation. In addition, a PhD dissertation is in progress, and will be completed in June 1994. Several publications are

expected to result, as well.

PUBLICATIONS: Henson, V.E. and Shaker, A.W., "Multilevel Methods for a Semilinear Elliptic Problem in the Flow of Pseudoplastic Fluids," in Proceedings of the 6th Copper Mountain Conference on Multigrid Method, NASA Conference Publication Number 3224, 1993.

CONFERENCE PRESENTATIONS: Henson, V. E. and Shaker, A.W., "Multilevel Methods for a Semilinear Elliptic Problem in the Flow of Pseudoplastic Fluids," 6th Copper Mountain Conference on Multigrid Methods, Copper Mtn, CO, 8 April 1993.

OTHER: A PhD dissertation is being written by MAJ Bruce T. Robinson, USA, under the direction of Prof. Henson. The topic of the dissertation, scheduled for completion in June, 1994, is "Multilevel Projection Methods for the Reconstruction of Images from Projections."

This project is ongoing research. Three papers are envisioned as output, along with the aforementioned PhD dissertation. The first of these papers, coauthored by Professor Henson, Major Robinson, and Professor Mark Limber (Simon Fraser University) has been submitted for presentation at the Colorado Conference on Iterative accepted for presentation scheduled for April, 1993, in Breckenridge, Colorado.

DOD KEY TECHNOLOGY AREA: Other.

KEYWORDS: Multilevel Methods.

A DISCRETE FOURIER TRANSFORM TUTORIAL

V.E. Henson, Assistant Professor

Department of Mathematics

W.L. Briggs, University of Colorado, Denver

Sponsor and Funding: None

OBJECTIVE: To write a tutorial on the Discrete Fourier Transform (DFT), aimed at a broad audience of engineers, scientists, and mathematicians. Certain sections on error analysis of the DFT include new results.

SUMMARY: This unfunded work is the joint work of Professor Henson and his dissertation advisor, Professor William L. Briggs (University of Colorado at Denver). It is designed to provide a tutorial level discussion of the DFT, which is at the heart of the Fast Fourier Transform (FFT), perhaps the most frequently used of all mathematical computer algorithms. Despite its enormous popularity and the many books written about the FFT, there

are many aspects of the DFT which are not widely publicized, and yet which critically affect the use and performance of the FFT. This text is sufficiently rigorous to present the many faces of the DFT in detail, while remaining accessible to readers with only a moderate background in mathematics. It is to be published by the Society for Industrial and Applied Mathematics.

OTHER: Briggs, W.L. and Henson, V.E., "A DFT Tutorial," Society for Industrial and Applied Mathematics, 393 pages, in press.

DOD KEY TECHNOLOGY AREA: Other.

KEYWORDS: Fourier Analysis, Fourier Transforms, FFT, DFT.

JAVELIN/TUG-V MODEL-TEST-MODEL

**B.K. Mansager, Adjunct Professor
Department of Mathematics**

Sponsor and Funding: TRADOC Analysis Command - Monterey

OBJECTIVE: The goal of this project is to further develop the M-T-M concept by investigating the influence of using combat simulations in the design of a field test and in post-test analysis.

SUMMARY: Began an effort to control variables within the Janus(A) combat model. Specifically, creating a "best fit" model representation of the Javelin and TUG-V systems, careful evaluation of the P_h and P_k data and analysis of the Ft. Hunter-Liggett terrain.

PUBLICATIONS: Neta, B. and Mansager, B., "Benefit of Sound Cueing in Combat Simulation," NPS Technical Report NPS-MA-94-003, 1993.

Cersovsky, D., Kleinschmidt, E., Neta, B., and Mansager, B., "Audio Detection Algorithms in Combat Simulations," International Journal of Mathematics and Computer Modeling, accepted, 1993.

Barr, D. and Mansager, B., "Terrain Map Resolution," International Journal of Mathematics and Computer Modeling, accepted, 1993.

CONFERENCE PRESENTATIONS: Mansager, B., "Model-Test-Model," Military

Operations Research Society C3IEW MOE II Workshop, Naval Postgraduate School, 24 March 1993.

THESES DIRECTED: Cersovski, D. and Kleinschmidt, E., CPTs, USA, "Mathematical Model of the Tactical Unmanned Ground Vehicle (TUGV) Using Computer Simulation," Master's Thesis, June 1993.

McGuire, Michael J., CPT, USA, "Comparison of the Dragon Antitank Weapon System (D'AW) to its Replacement, the Javelin," Master's Thesis, September 1993.

McFadden, Willie J., CPT, USA "Comparison of the Janus(A) Simulated Vegetation Codes for the Javelin Antitank Operational Test," Master's Thesis, September 1993.

OTHER: Provided TRAC-Monterey a computer representation of the Javelin antitank system and the TUGV. Also provided a updated terrain data base for the Ft. Hunter Liggett terrain.

DOD KEY TECHNOLOGY AREA: Other.

KEYWORDS: Antitank Systems, Audio Sensors, Model-Test-Model.

AUDIO DETECTION ALGORITHMS

B. Neta, Professor

Department of Mathematics

Sponsor and Funding: TRADOC Analysis Command - Monterey

OBJECTIVE: To develop sound algorithm and to incorporate it into the Janus simulation.

SUMMARY: It is known that audio cueing plays an important role in detection and acquisition of targets on the battlefield. Current combat simulations such as Janus play visual detection processes, and use them to generate target lists from which engagements are drawn. At present, there is not a comparable algorithm for playing audio cueing. The work proposed is designed to investigate how such cueing could be incorporated into the Janus simulation.

PUBLICATIONS: Cersovsky, D., Kleinschmidt, E., Neta, B., and Mansager, B., "Audio Detection

Algorithms in Combat Simulations," International Journal of Mathematical and Computer Modelling, accepted for publication.

Neta, B. and Mansager, B., "Benefit of Sound Cueing in Combat Simulation," NPS Technical Report NPS-MA-94-003, October 1993.

THESIS DIRECTED: Kleinschmidt, Ed and Cersovski, Don, "Mathematical Model and Analysis of the Tactical Unmanned Ground Vehicle (TUG-V) Using Computer Simulation," Master's Thesis in Applied Mathematics, 1993.

DOD KEY TECHNOLOGY AREA: Software.

KEYWORDS: Audio Detection, Janus, Combat Simulation.

DEVELOPMENT OF FINITE ELEMENT PREDICTION MODEL

B. Neta, Professor
Department of Mathematics
Sponsor and Funding: Unfunded

OBJECTIVE: To investigate the feasibility of parallel computers to efficiently solve the shallow water equations using the finite element method.

SUMMARY: We have concentrated on parallel computation using the INTEL hypercube and the MasPar (massively parallel computer) for problems related to weather forecasting. We have developed a domain decomposition finite difference conservative scheme for the hypercube and a highly accurate model for the massively parallel computer.

PUBLICATIONS: Neta, B. and Lustman, L., "Parallel Conservative Scheme for Solving the Shallow Water Equations," Monthly Weather Review, Vol. 121 pp. 305-309, 1993.

Neta, B. and Thanakij, R., "Finite Element Approximation of the Shallow Water Equations on the MasPar in Advances in Finite Element Analysis in Fluid Dynamics," M.N. Dhaubhadel, M.S. Engleman, W.G. Habashi, eds., FED - Vol. 171, American Society of

Mechanical Engineering, 1993.

Neta, B. and Thanakij, R., "Finite Element Approximation of the Shallow Water Equations on the MasPar," NPS Technical Report NPS-MA-93-014, April 1993.

CONFERENCE PRESENTATIONS: Neta, B., "Finite Element Approximation of the Shallow Water Equations on the MasPar," Fourth Navy R&D Information Exchange Conference, NRAD, San Diego, CA, 13-15 April 1993.

Neta, B., "Finite Element Approximation of the Shallow Water Equations on the MasPar," 1993 American Society of Mechanical Engineering Winter Annual Meeting, New Orleans, LA, 28 November -3 December 1993.

DOD KEY TECHNOLOGY AREA: Computers.

KEYWORDS: Parallel Computing, Shallow Water Equations, Weather Prediction, Massively Parallel Computer.

MULTILINEAR EXTENSIONS OF GAMES AND APPLICATIONS

G. Owen, Professor

Department of Mathematics

Sponsor and Funding: National Science Foundation

OBJECTIVE: The purpose of this research was to analyze the mathematical properties of multilinear extensions (MLE's) and study their possible applications to problems in economics, management, and political science.

SUMMARY: The MLE was used to show a serious discrepancy between the non-atomic game (infinite player) model in current use and the asymptotic behavior of the finite player model. MLE's were also used to calculate certain modified values as cost allocation rules for communication situations. Further, MLE's were used to calculate voting power in the case of corporations with interlocking directors.

I spent the spring quarter (Q-III of AY93) and the fall quarter (Q-I of AY94) working on research, mainly in Barcelona, Spain, Tilburg, Netherlands, and Jerusalem, Israel.

PUBLICATIONS: Owen, G., "The Not-

Quite Non-Atomic Game: Normal Approximation," International Journal of Game Theory, Vol. 21, pp. 405-417.

Owen, G., Nouweland, A.v.d., Borm, P., and Tijs, S., "Cost Allocation and Communication," Naval Research Logistics, Vol. 40, pp. 733-744.

CONFERENCE PRESENTATION: Owen, G., "Group Effects in Voting," Public Choice Society meeting, New Orleans, LA, 21 March 1993.

THESES DIRECTED: Co-Director for "Graphs and Communication in Games," by Anne van den Nouweland, Ph. D. Dissertation at Catholic University of Brabant, Tilburg, Netherlands, March 1993.

DOD KEY TECHNOLOGY AREA: Other.

KEYWORDS: Multilinear Extension, Games.

CLASSIFICATION OF GRAPHS
WITH EFFICIENTLY COLORABLE COMPETITION GRAPHS

C.W. Rasmussen, Assistant Professor
Department of Mathematics

Sponsor and Funding: Naval Postgraduate School

OBJECTIVE: This is a continuing project aimed at identifying classes of graphs whose competition graphs have good coloring properties. Such graphs would be of use in practice obtaining exact solutions to variety of resource allocation problems.

SUMMARY: This summary covers the first year of a project for which funding has been extended for a second year. The work has yielded interesting results, and promises to continue to do so. The primary focus has been on classification of undirected graphs whose competition graphs fall into the class of interval graphs. The competition graph of a loopless undirected graph is its two-step graph, while the competition graph of an undirected graph possessing loops at every vertex is the square of the graph obtained by deletion of all loops. The characterization of undirected graphs with interval squares and interval two-step graphs has been completed. Remaining in this vein, then, are (i) the study of graphs whose competition graphs fall into neither of these boundary categories, and (ii) the study of graphs whose squares/two-step graphs fall into other classes that show good coloring properties. Preliminary results in these directions are promising.

PUBLICATIONS: Lundgren, J.R., Maybee, J.S., and Rasmussen, C.W., "Interval Competition Graphs of Symmetric Digraphs," Discrete Mathematics, Vol. 119, pp. 113-122.

Lundgren, J.R. and Rasmussen, C.W.,

"Two-step Graphs of Trees," Discrete Mathematics, Vol. 119, pp. 123-139.

CONFERENCE PRESENTATIONS: Lundgren, J.R., Merz, S.K., and Rasmussen, C.W., "On Direct Computation of Chromatic Numbers of Competition Graphs." A preliminary report was presented by this author at the 24th Southeastern International Conference on Combinatorics, Graph Theory, and Computing, held at Florida Atlantic University in February 1993. The full paper was presented by this author at an invitational conference on Graphs and Matrices held in Boulder, Colorado in May 1993, on the occasion of Professor John S. Maybee's retirement from the Department of Mathematics of the University of Colorado at Boulder.

Lundgren, J.R., Merz, S.K., and Rasmussen, C.W., "Characterization of Graphs with Interval Squares," 24th Southeastern International Conference on Combinatorics, Graph Theory, and Computing, Florida Atlantic University, February 1993.

Lundgren, J.R., Maybee, J.S., Merz, S.K., and Rasmussen, C.W., "Characterization of Graphs With Interval Two-Step Graphs," invitational conference on Graphs and Matrices, Boulder, CO, May 1993.

OTHER: Two additional papers were completed in 1993. They have been submitted for publication as NPS Technical Reports, and are in review at Linear Algebra and its Applications.

DOD KEY TECHNOLOGY AREA: Communica-
tions Networking, Other.

KEYWORDS: Graph Coloring,
Competition Graphs, Interval Graphs.

**DEPARTMENT
OF
MATHEMATICS**

**1993
Faculty Publications
and Presentations**

JOURNAL ARTICLES

Borges, C.F. and Gragg, W.B., "A Parallel Divide and Conquer Algorithm for the Generalized Real Symmetric Definite Tridiagonal Eigenproblem," in Numerical Linear Algebra and Scientific Computing, L. Reichel, A. Ruttan, and R.S. Varga, eds., de Gruyter, Berlin, pp. 11-29, 1993.

Borges, C.F., Frezza, R., and Gragg, W.B., "Some Inverse Eigenproblems for Jacobi and Arrow Matrices," Journal of Numerical Linear Algebra Applications, 1993.

Canright, D. and Morris, S., "Buoyant Instability of a Viscous Film Over a Passive Fluid," Journal of Fluid Mechanics, Vol. 255, pp. 349-372, October 1993.

Frenzen, C.L., "Explicit Mean Energies for the Thermodynamics of Systems of Finite Sequences," Journal of Physics A: Math Gen., Vol. 26, pp. 2269-2273, 1993.

Frenzen, C.L. and Fischer, I., "On a Conjecture of Pierce for Permanents of Singular Correlation Matrices," SIAM Journal on Matrix Analysis Applications, Vol. 14, No. 1, pp. 74-81, 1993.

Gragg, W.B. and Demmel, J.W., "On Computing Accurate Singular Values and Eigenvalues of Matrices with Acyclic Graphs," Linear Algebra and its Applications, Vol. pp. 203-218, 1993.

Gragg, W.B., Ammar, G.S., and Reichel, L., "An Analogue for Szego Polynomials of the Clenshaw Algorithm," Journal of Computational and Applied Mathematics, Vol. 46, pp. 211-216, 1993.

Gragg, W.B., "Positive Definite Toeplitz Matrices, the Arnoldi Process for Isometric Operators, and Gaussian Quadrature on the Unit Circle," Journal of Computational and Applied Mathematics, Vol. 46, pp. 183-198, 1993.

Lundgren, J.R. and Maybee, J.S. and Rasmussen, C.W., "Interval Competition Graphs of Symmetric Digraphs," Discrete Mathematics, Vol. 119, pp. 113-122, 1993.

Lundgren, J.R. and Rasmussen, C.W., "Two-step Graphs of Trees," Discrete Mathematics, Vol. 119, pp. 123-139, 1993.

Neta, E. and Lustman, L., "Parallel Conservative Scheme for Solving the Shallow Water Equations," Monthly Weather Review, Vol. 121, pp. 305-309, 1993.

Phipps, W.E., Neta, E., and Danielson, D.A., "Parallelization of the Naval Space Surveillance Satellite Motion Model," Journal of Astronautical Sciences, Vol. 41, pp. 207-216, 1993.

Owen, G., Nouweland, A.v.d., Borm, P., and Tijis, S., "The Not-Quite Non-Atomic Game: Normal Approximation," International Journal of Game Theory, Vol. 21, pp. 405-417.

J., G., Nouweland, A.v.d., Borm, P., and Tijis, S., "Cost Allocation and Communication," Naval Research Logistics, Vol. 40, pp. 733-744.

Scandrett, C. and Kriegsmann, G.A., "Large Membrane Array Scattering," Journal of the Acoustical Society of America, Vol 93, No. 6, June 1993.

Weir, Maurice, Barr, D., and Hoffman, J., "An Indicator of Combat Success," Naval Research Logistics, Vol. 40, pp. 755-768, 1993.

CONFERENCE PUBLICATIONS

Borges, C.F. and Frezza, R., "On Model Identification of Gaussian Reciprocal Processes from the Eigenstructure of Their Covariances," in *Computation and Control III: in Proceedings of the Third Boxeman Conference*, J. Lund and K. Bowers, Eds., *Progress in Systems and Control Theory*, Birkhauser, (1993), pp. 63-72.

Cavanaugh, K. J. and Henson, V. E., "A Multilevel Cost-Space Approach to Solving the Balanced Long Transportation Problem," in *Proceedings of the 6th Copper Mountain Conference on Multigrid Methods*, NASA Conference Publication Number 3224, 1993.

Danielson, D.A., "Semianalytic Satellite Theory: Mathematical Algorithms," in *Proceedings of the 1993 Space Surveillance Workshop*, M.I.T. Lincoln Lab, Lexington, MA, Vol. 2, pp. 61-70, 30 March-1 April 1993.

Danielson, D.A., "Semianalytic Satellite Theory: Second Order Expansions in the true Longitude L ," in *Proceedings of the AAS/AIAA Astrodynamics Conference*, Victoria, BC, AAS 93-720, 16-19 August 1993.

Gragg, W.B., Ammar, G.S., and Reichel, L., "Direct and Inverse Unitary Eigenproblems in Signal Processing: An Overview," in *Proceedings of Linear Algebra for Large Scale and Real Time Applications*, M.S. Moonen, G.H. Golub and B.L.R. De Moor, Eds., NATO ASI Series E, Volume 232, Kluwer Academic Publishers, Dordrecht, The Netherlands, pp. 341-343, 1993.

Henson, V. E. and Shaker, A. W., "Multilevel Methods for a Semilinear Elliptic Problem in the Flow of Pseudoplastic Fluids," in *Proceedings of the 6th Copper Mountain Conference on Multigrid Methods*, NASA Conference Publication Number 3224, 1993.

Neta, B., "Parallel Solution of Initial Value Problem," in *Proceedings of the Fourth International Colloquium on Differential Equations*, Plovdiv, Bulgaria, 18-23 August 1993.

Neta, B., and Thanakij, R., "Finite Element Approximation of the Shallow Water Equations on the MasPar in Advances in Finite Element Analysis in Fluid Dynamics," M.N. Dhaubhadel, M.S. Engleman, W.G. Habashi, eds., *FED- Volume 171, American Society of Mechanical Engineering*, 1993.

Phipps, W.E., Neta, B., and Danielson, D.A., "Parallelization of the Naval Space Surveillance Satellite Motion Model," in *Proceedings of the 1993 Space Surveillance Workshop*, M.I.T. Lincoln Lab, Lexington, MA., R. W. Miller, R. Sridharan, Eds., Vol. 2, pp. 71-79, 30 March - 1 April 1993.

CONFERENCE PRESENTATIONS

Borges, C.F., "A Parallel Divide and Conquer Algorithm for the Generalized Real Symmetric Definite Tridiagonal Eigenproblem," Third SIAM Conference on Linear Algebra, Signals, Systems, and Control, University of Washington, Seattle, 19 August 1993.

Cavanaugh, K.J. and Henson, V. E., "A Multilevel Cost-Space Approach to Solving the Balanced Long Transportation Problem," 6th Copper Mountain Conference on Multigrid Methods, Copper Mtn, CO, 7 April 1993.

Danielson, D.A., "Semianalytic Satellite Theory: Mathematical Algorithms," Space Surveillance Workshop, M.I.T. Lincoln Lab, Lexington, MA, 1 April 1993.

Danielson, D.A., "Semianalytic Satellite Theory: Second Order Expansions in the true Longitude L," AAS/AIAA Astrodynamics Conference, Victoria, BC, 17 August 1993.

Franke, R., "Least Squares Surface Approximation Using Multiquadric Functions," Topics in CAGD '93, Wolfenbuettel, Germany, June 1993.

Franke, R., "Least Squares Surface Approximation Using Multiquadric Functions," Geometric Modelling, Dagstuhl Seminars, Schloss Dagstuhl, Germany, June 1993.

Franke, R., "Least Squares Approximation using Multiquadric Functions," SIAM Conference on Geometric Design, Tempe, AZ, November 1993

Frenzen, C.L., "A Conjecture of Pierce for Permanents of Singular Correlation Matrices," Society of Industrial and Applied Mathematics National Meeting, Philadelphia, PA, July 1993.

Gragg, W.B., "A Parallel Divide and Conquer Algorithm for the Generalized Real Symmetric Definite Tridiagonal Eigenproblem," Navy Research and Development Conference, NRD, San Diego, CA, 14 April 1993.

Gragg, W.B. and C.F. Borges, "A Parallel Divide and Conquer Algorithm for the Generalized Real Symmetric Definite Tridiagonal Eigenproblem," invited, 882nd Meeting of the American Mathematical Society, Northern Illinois University, DeKalb, IL, 24 May 1993.

Henson, V. E. and Shaker, A. W., "Multilevel Methods for a Semilinear Elliptic Problem in the Flow of Pseudoplastic Fluids," 6th Copper Mountain Conference on Multigrid Methods, Copper Mountain, Colorado, 8 April 1993.

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Neta, B., "Parallel Solution of Initial Value Problem," Fourth International Colloquium on Differential Equations, Plovdiv, Bulgaria, 18-23 August 1993.

Neta, B., "Orbit Prediction on Parallel Computers," (MIMD Machines and PVM), Parallel Processing Forum, Phillips Lab./VTA, Kirtland AFB, NM, 8 December 1993.

Neta, B., "Finite Element Approximation of the Shallow Water Equations on the MasPar," Fourth Navy R&D Information Exchange Conference, NRAD, San Diego, CA, 13-15 April 1993.

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Owen, G., "The Not-Quite Non-Atomic Game," University of Tilburg, Netherlands, 5 February 1993; University of Bergamo, Italy, 2 April 1993; University of Marseille, France, 14 April 1993; Autonomous University of Barcelona, Spain, 21 April 1993; University of Toulouse, France, 27 April 1993; Complutense University, Somosaguas, Spain, 11 May 1993; University of Santiago de Compostela, Spain, 20 May 1993; University of the Basque Country, Bilbao, Spain, 24 May 1993; University of Caen, France, 28 May 1993; London School of Economics, London, U.K., 4 June 1993; Hebrew University of Jerusalem, Israel, 13 June 1993; and the University of Alicante, Spain, 26 November 1993.

Owen, G., "Group Effects in Voting," Public Choice Society Meeting, New Orleans, LA, 21 March 1993.

Owen, G., "Recent Results in Game Theory," University of Siena, Italy, 31 March - 1 April 1993; and the University of Bergamo, Italy, 12 November 1993.

Owen, G., "Indirect Control of Corporations," University of Bergamo, Italy, 3 April 1993; Polytechnic University of Catalonia, Terrasa, Spain, 5 May 1993; and the Complutense University, Madrid, Spain, 10 May 1993.

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Owen, G., "Convergence of the Consistent Solution," Institute for Economic Analysis, Bellaterra, Spain, 25 November 1993.

Scandrett, C. and Canright, D., "Low Frequency Active Array Calculations in a Shallow Channel," Annual Meeting of the Society for Industrial and Applied Mathematics, Philadelphia, PA, 12-16 July 1993.

COLLOQUIUM PRESENTATIONS

Gragg, W.B., "Divide and Conquer Algorithms for Structured Eigenvalue Problems," Department of Mathematical Sciences, Simon Fraser University, Vancouver, Canada, 22 April 1993.

Gragg, W.B., "A Parallel Divide and Conquer Algorithm for the Generalized Real Symmetric Definite Tridiagonal Eigenproblem," Department of Computer Science, University of Utah, Salt Lake City, 20 May 1993.

Gragg, W.B., "Divide and Conquer Algorithms for Structured Eigenvalue Problems," Department of Mathematics, University of Bremen, Germany, 24 August 1993.

Gragg, W.B., "Going Around on Circles," Department of Mathematics, University of Bremen, Germany, 26 August 1993.

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TECHNICAL REPORTS

Canright, D., "Analysis of Thermocapillary Convection in Welding," NPS Technical Report NPS-MA-93-011, March 1993.

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Franke, R. and Freeden, W., "Generalized Weighted Spline Approximation on the Sphere," Nr. 98 (to be submitted to SIAM Journal on Scientific Computing).

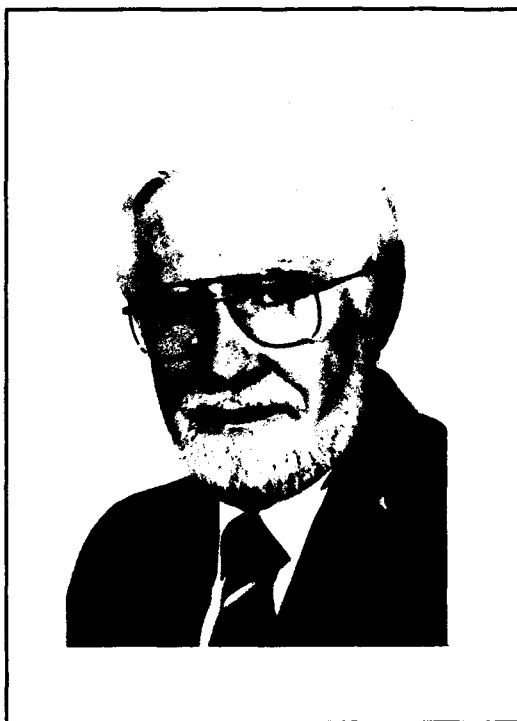
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**DEPARTMENT
OF
MECHANICAL ENGINEERING**



**Matthew D. Kelleher
Chairman**

DEPARTMENT OF MECHANICAL ENGINEERING

The Department of Mechanical Engineering's research program continues to advance the state of knowledge in areas of importance to the U.S. Navy, in particular, those areas involving solid mechanics and composite structures; underwater shock and vibration/noise; control of dynamic systems; applications to electronic cooling, welding, boiling and condensation, and applied thermodynamics; and materials science applied to metals and metal matrix composites. Results of research are published in student theses, NPS technical reports, and in papers presented both at, and appearing in, national conference proceedings, and published in scientific journals. The following is an overview of each area of research with individual faculty summaries.

SOLID MECHANICS, SHOCK AND VIBRATION

Professor Shin has continued his investigation of "Response of Naval Structures to Underwater Explosions" under the sponsorship of the Defense Nuclear Agency (DNA), Naval Surface Warfare Center (NSWC) - Annapolis Detachment, and Naval Sea Systems Command (NAVSEA). For DNA project, the analytical and numerical studies of underwater explosion and its effect to the naval structures have been conducted. There are three basic features; (i) shock wave propagation through the surrounding hydro-acoustic medium and the behavior of explosive-gas bubble, (ii) structural dynamics problems with material and geometric nonlinearities, and (iii) fluid-structure interaction and explosive gas bubble - structure interaction. The scientific objective of NAVSEA project is to simulate the ship-shock environment and its effect to shipboard combat systems using Navy's mediumweight shock machine with tuned mounting fixture. The multi-DOF tuned deck simulator has been designed, and fabricated in FY-93. The shock testing was performed using U.S. Navy's mediumweight shock machine with designed tuned deck simulator and the analytical results were compared with those of tests. Addendum to MIL-S-901D was proposed to the mediumweight shock qualification procedures. NSWC-Annapolis has been developing Advanced Lightweight Influence Sweep System (ALISS). ALISS is an Advanced Technology Demonstration to validate the feasibility of superconducting technology to sweep magnetic influence mines in shallow water. Under the extremes of shock and vibration environment, the high magnetic field of the superconducting coil may collapse and jeopardize its mission. We developed operational shock and vibration criteria to be designed into ALISS and have been performed numerical simulation of dynamic response of superconductor magnet.

Professor Shin has also conducted an investigation of time-frequency domain distribution and its application to reciprocating machinery analysis from the standpoint of machinery condition monitoring and diagnostics. Pseudo Wigner-Ville distribution and wavelet transform were used to characterize the non-stationary signatures in time-frequency domain. The project was sponsored by NAVSEADET PERA(CV).

Professor Kwon's recent research includes failure and damage modeling of fibrous composites, a biomechanical study of the human knee joint, and a study of dynamic structural response caused by underwater explosion. These researches have been

sponsored by Naval Surface Warfare Center, Naval Hospital, and Defense Nuclear Agency. The failure and damage study of composites considers a micro-macro model. The study links the micromechanics model and the macromechanics model to analyze fibrous composite structures. As a result, this model can analyze a general shape of composite structure and can still find the damage progression and failure at the fiber and matrix level. Another study is to investigate the compressive residual strength of balanced or unbalanced sandwich composite structures subjected to impact loads. The effect of local delamination is also included in the study. Professor Kwon develops a kinematic model to study the motion of the human knee joint. Using this model, behaviors of intact, posterior cruciate ligament (PCL) injured and reconstructed knees are studied and compared. This model will help to determine the best reconstructed knees are studied and compared. This model will help to determine the best reconstruction technique for the PCL injury. The underwater shock research includes the study of the effect of surface coating, response of air- or water-backed composite structures, and development of simplified mathematical modeling techniques for complicated naval structures.

Professor Gordis is conducting research in several areas in structural dynamics and vibration. In structural synthesis, a family of analytic methods have been developed which allow the direct calculation of modified dynamic response of structural dynamic system computer models which have been arbitrarily modified and/or combined with other models. These methods are distinguished by their ability to treat modification of arbitrary size, distribution and damping, and that the methods provide a highly efficient and exact solution in all cases. Research is also being performed in structural system identification, where deficiencies in math models are identified through the use of measured dynamic response data. Recent results here include the identification of a nonstandard set of eigenvalues which provide an additional, independent data with which to tackle the underdetermined system identification problem. The system identification methods are being applied in the area of structural damage detection, which seeks to uncover structural damage in components using measured dynamic response data. Additional areas of research include the optimization of shipboard topside equipment with respect to weapons effects.

SHIP SYSTEMS

Professor Calvano has been conducting a study for the Naval Sea Systems Command (NAVSEA) to investigate methods for improving the design of survivability features for surface ships, within cost constraints, as well as methods for the assessment of ship survivability. This work is intended to build a basis for long-term support of NAVSEA in Total Ship Survivability as related to the engineering of total ship systems. The task is being approached using the ship design process as a frame of reference to explore ways to further the development of survivability as an integral element of that process. Professor Calvano has also been investigating methods for assessing the mission survivability of surface ships and the technology used to enhance their survivability. An analysis of the value of a modern warship's staying power (anti-vulnerability) relative to the value of defensive firepower and other measures for so-called active survivability (anti-susceptibility), offensive firepower, and detection and tracking power are being studied.

DYNAMIC SYSTEMS, CONTROLS AND ROBOTICS

Professor Healey has continued his activities in the development of advanced control technology for Autonomous Underwater Vehicles (AUV). These vehicles are robotic unmanned submersibles that are being considered in many countries in the world for a variety of missions encompassing both military and civilian activity. The need for advanced intelligent control technology lies in the requirement to operate these vehicles independently from a surface ship. Past and current practice is to use submersibles that are tethered to a surface ship thereby receiving power from the ship and control commands from a pilot. Sensory signals are transmitted back to the operator and thus these vehicles fall within the class of 'teleoperated robots'. Because tether management is burdensome and places large uncertain loading on the vehicle, the elimination of the tether is the primary goal of AUV technology leaving vehicle communications to acoustic modems (acoustic tethers) which operate at low baud rate, cannot provide power. High degrees of intelligence, and moderate sustaining energy storage are therefore required onboard the vehicle so that it can perform mission control functions in response to short high level commands from the user. The automation of the piloting functions is done with autopilots, and a degree of automated reconfiguration of control and sensing functions is a requirement.

Under a grant from NSF, joint with Professor McGhee (CS), this program is engaged in the investigation of the design of reconfigurable controllers that will exhibit ease of modification and be sufficiently intelligent to perform self recovery from both mission and vehicle systems faults. The system is based on tri-level software architecture that contains a rule based controller at the highest (STRATEGIC) level, a TACTICAL level controller that coordinates the commands and requests for mission state information. The upper two levels run asynchronously, and operate as a discrete event system to pass appropriate commands and requests to and receive the lowest (EXECUTION) level software. This level runs the real time systems configuring the sensing, control function, and actuation activity of the vehicle. The hardware and software developed to date runs an Autonomous Vehicle called the NPS Phoenix in cruise and hovering missions in a test tank. One particularly important aspect of this work is to define the best computer/robot language to use. Collaborators in France have developed a language called 'ESTEREL' which is a way of linguistically encoding a finite state machine (automaton) representing the mission controller. Collaborators in Portugal have written a language called 'CORAL' which encodes a Petri net description of a mission controller, whereas the Naval Postgraduate favors the use of an already established AI language called 'PROLOG' in a special form that encodes either Petri net or Finite State Machine descriptions. We have demonstrated that the vehicle can already perform complex robotic tasks in a coordinated way, and are continuing to increase the level of intelligence that is built into the mission controller.

With funding from ONR, Professor Healey, in collaboration with Professor Cristi (EC), is investigating the use of high frequency sonar to navigate autonomous vehicles to a local scene. While navigation to a global reference is of course important, other missions involve the returning to a previous site and the need to locally navigate to landmarks within the site. Landmarks can be active or passive beacons. The use of nonlinear filters using potential functions to update a local map is expected to provide local area navigation when fused with

sonar returns and vehicle motion measurements.

With funds from the Navy Explosive Ordnance Disposal Technical Center, Professor Healey is exploring the development of graphics based simulators to illustrate the use of multiple agent Subsumption robots for munitions clearance. The work has begun this year and is expected to continue as a tool for the evaluation of clearance technologies. To date the basic terrain model has been built based on the US Marine Corps Twentynine Palms facility digitized on a meter square grid to approximately 2 cm. vertical accuracy. Objects representing a variety of scatterable munitions can be placed on the terrain and up to ten walking robots, represented faithfully for kinematic motion, may be simulated. Professor Healey is also exploring the use of the AI language 'PROLOG' as a device for designing rule based design optimization systems initially funding by NAVSEA. Design involves both synthesis and analysis. This work was jointly investigated with Professor Gordis using rapid frequency response techniques for the structural analysis that ultimately would be tied to the rule based synthesis.

In the area of robotics, Professor Driels has been conducting research into two main areas. The first of these concerns the improvement in robot accuracy through a manipulator calibration process. In particular, the use of closed loop kinematic constraints instead of precision measuring systems is investigated. This leads to a calibration process which is rapid, inexpensive, and may be performed in the robot workplace. In a second project, the implementation of bilateral force feedback in hydraulic teleoperator systems is investigated. In this work, single and two DOF systems have been constructed and tested. Instabilities due to inertial loading have been observed and analyzed. Further work to design small, lightweight force reflecting elements is under way. Both of these projects are supported with a reimbursable grant from NASA Johnson Space Center.

Professor Driels has also been carrying out research for the U.S. Army in the area of combat simulation modeling. Currently, the Army uses a simulation called Janus for training mounted and dismounted troops in combat. The simulation takes place between two opposing forces on a simulated battlefield with a 100m grid for the terrain. Current work is focused on using a high fidelity terrain grid of 1m, thereby enhancing the realism with which the simulation is conducted. In particular, Dr. Driels is addressing the manner in which conventional acquisition and detection algorithms may be used in the higher resolution database, and what modifications would make algorithms closer to the actual process.

Professor Papoulias has been engaged in studies of submarine dynamics and advanced marine vehicles. Specifically, he has been studying frictional and wave-making resistance characteristics of SLICE hull; a new hull design that incorporates many of the advantages in powering and seakeeping of small waterplane area twin hull types with the added flexibility of separate fore/aft buoyancy modules. The above studies are towards establishing design guidelines and regions of advantage/disadvantage of SLICE versus traditional SWATH hulls. In conjunction with his co-principal investigator, Professor Calvano, he has also started studies on structural response of the above hull type. This project, which is being funded by the Office of Naval Research, is continuing during this current year as well. Another main area of research has been on submarine dynamics in shallow and littoral waters. This is a new area of naval operations

which is expected to become very important in the future. Professor Papoulias' studies in the problems, have been on two fronts, namely operational and tactical characterization, and determination of free surface and proximity forces and moments. In the first task, mission objectives and requirements have been established for shallow water/periscope depth operations, while in the second task, panel methods have been utilized to obtain the pressure distribution on the body and the resulting forces and moments. This project, which is supported by the Naval Surface Warfare Center, will be continuing during FY 95 as well.

Professor Mukherjee is engaged in theoretical and experimental robotics research. The experimental research project aims at the design, development and testing of a flexible robotic manipulator for minimally invasive surgical applications. Such manipulators are expected to provide surgeons with dexterity inside the human torso during minimally invasive surgical procedures. Currently research is underway for the development Superelastic Alloy (SEA) actuators for the manipulator, the design of the actuation systems, feedback control of the actuators, the design of the flexible manipulator which needs to meet a number of stringent requirements, and the development of the interface. The second project is more theoretical in nature and addresses the repeatability problem in nonholonomic systems. In redundant robot manipulators under non-conservative control laws such as pseudoinverse control, the problem translates to the design of closed workspace trajectories that will map to closed joint space trajectories. This will reduce the possibility of collision in a clustered workspace, and will eliminate time required for reconfiguration. With repeatable trajectories space manipulators will be able to perform repeated tasks without losing their attitude in space. A couple of associated problems that are also being addressed are related to the stability of the repeatable trajectories and the design of feedback control laws for repeatable motion.

FLUID DYNAMICS, HEAT TRANSFER AND TURBOMACHINERY

Professor Sarpkaya has been working on basic research towards the understanding of the fundamental mechanisms and physical processes underlying two- and three-dimensional vortex/free-surface interactions in homogeneous, stratified, and sheared media, taking into account ambient turbulence, viscous effects, and various large-scale instabilities (sinusoidal instability and vortex breakdown) for ship and submarine related hydrodynamics in a real ocean environment (ONR). Numerous physical experiments have been carried out in a large towing tank with various lifting surfaces and submerged bodies in homogeneous and density-stratified medium. Second, experiments with single and multiple vortices have been conducted in large water basin using both stratified and homogenous medium. Third, experiments have been performed in a recirculating water tunnel with a single turbulent vortex. The velocity and turbulence measurements were made with a LDV system. The characteristics of the resulting surface scars have been evaluated in terms of the governing parameters through the use of a Motion Analysis System and a Sun computer. Extensive numerical analysis has been performed and a computer code has been developed to predict numerically the characteristics of the surface disturbances, the energy spectra, the distribution of the turbulent kinetic energy, and the fractal dimension. Professor Sarpkaya, under the sponsorship of the Naval Projects Research Office (NPRO), also has been conducting computational and physical experiments towards the understanding of

wake collapse in stratified flows. In this work, a towing tank is used to tow bodies at various speeds in an arbitrary density-stratified medium and to measure the turbulence intensities at various locations as a function of time. The statistical analysis of the resulting data help to determine the generation and propagation of internal waves and the consequences of wake collapse on the distribution of turbulent kinetic energy.

Professor Marto continued his research on enhanced two-phase heat transfer. The influence of wall conductivity on film condensation of steam on a horizontal integral-fin tube was determined. Additional nucleate boiling data of CFC-114 and HCFC-124 were obtained during boiling from various enhanced surfaces. The influence of oil on boiling performance was also studied.

Professor Kelleher has continued the investigation of advanced techniques for liquid cooling of electronic equipment under the sponsorship of the Naval Surface Warfare Center, Crane, Indiana. A study has been undertaken to investigate the heat transfer performance characteristics of internally finned, liquid flow through modules. As part of this study a large scale model of the internally finned flow passage has been built to investigate the complex convective heat transfer processes associated with internal flow in passages with staggered fins. Experiments are also being conducted using actual flow through modules. In attempting to understand the fundamental heat transfer processes involved with liquid immersion cooling of electronic equipment, experiments on the boiling characteristics of highly wetting fluorinated hydrocarbon liquids are also being carried out. Professor Kelleher has been continuing the work on the field modeling of fire and smoke spread in confined spaces. In this work, finite difference model to simulate the spread of fire and smoke in the fire simulation experimental facility at the Naval Air Warfare Center has been developed. The present version of the model uses a system of general orthogonal coordinates so that the specification of the geometry is not a major constraint. The code has been used to model fires in the experimental facility currently in operation at the Naval Air Warfare Center, China Lake, CA. Results have been obtained for simulations of fires in this facility both with and without a ventilation opening in the side wall. Professor Kelleher is also investigating the heat transfer characteristics of the superconducting magnet designs for use in the Advanced Lightweight Influence Sweep System (ALISS). ALISS is an Advanced Technology Demonstration being carried out by the Naval Surface Warfare Center, Annapolis. In the present investigation, the magnet structure is being numerically modeled as an orthotropic solid. The effects on quenching of the heat leaks associated with the electrical and structural connections are being studied.

Professor Milsaps' research is concerned with several aspects of energy conversion, power generation and propulsion. The specific research focus is on fluid/structural problems in gas turbine engine components. The most recent work has been on fluid induced synchronous vibration problems from rotating, non-uniform labyrinth seals. Simple lumped parameter models, Computational Fluid Dynamic (CFD) and experimental methods were used. A new experimental facility has been designated to measure the flow in advanced geometry seals. LDA and hot wire measurements will be made. In addition, an experimental and analytical rotodynamics research program has been conducted to study various complex vibration phenomena, such as split resonance and backward whirl, induced by asymmetric systems. Various asymmetries including, gravity, journal bearing

sleeve imperfections, etc. have been investigated. Rotodynamic coefficients have been found by using parameter identification techniques and comparison of model predictions to experimental results. In conjunction with this effort, an analytical investigation of advanced magnetic bearing concepts for naval applications has been conducted. The use of magnetic bearings in turbines, pumps, gears, main propulsion shafting, etc., in surface combatants and submarines can lead to a significant reduction in structure-borne acoustic signatures.

MATERIALS SCIENCE

Professor Perkins is continuing his investigation of the mechanisms of lattice transformations and internal friction in high-damping alloys. The main objective of this research is to develop models to delineate the damping mechanisms in certain so-called "quiet metals". The ultimate aim is to develop, on the microscopic and sub-microscopic level, an unified mechanistic model for the damping behavior of high damping alloys. Since results to date indicate that damping in these alloys is always linked to phase transformations (which may be magnetic transitions, lattice-displacive transformations, or disiffusional transformations), and more particularly to boundaries which result from such transformations, a major objective is to define the microstructural features which play a role in the damping mechanisms.

Professor McMelley has initiated a cooperative research and development (CRADA) program in processing of aluminum-based metal matrix composite material with funding from Duralcan-USA, a composites manufacturer located in San Diego, CA. This work has involved the adaptation of processing methodologies developed at the Naval Postgraduate School to the manufacture of such composite materials. It is now possible to achieve strength/ductility combinations in metal matrix composites which are comparable of those of unreinforced materials, thus dispelling the notion that these composites are inherently brittle. This program will attempt to transfer technology from the Department of Defense to industry while simultaneously enhancing the utility of these materials in military systems. Research into processing and superplasticity in aluminum alloys as well as sensor development for the intelligent heat treating of materials has also continued. The work on superplastic aluminum has focused on the evolution during processing of grain boundary types necessary for extensive superplastic response. A sensor system has been developed that can monitor in real time the aging response of age-hardenable materials. In conjunction with a controller, such a sensor system will allow more precise control of heat treatment processes and thereby reduce materials variability while improving system reliability.

Professor Fox has been continuing his work in collaboration with the Annapolis Detachment of the Carderock Division of the Naval Surface Warfare Center on the correlations between mechanical properties and microstructure of Navy high strength steels and their weldments so that new weld consumables and parent steels for Naval applications can be developed. In addition, two projects are being undertaken in collaboration with the Naval Air Warfare Center, Warminster, PA. The first involves the characterization of the hot salt corrosion of silicon carbide fiber-reinforced glass ceramic matrix composites which are potential lightweight replacements for nickel-based superalloys in high temperature aero-

engine applications and the second concerns the microstructural characterization of new high temperature intermetallic alloys (including TiAl) and NiAl) using new methods in x-ray and electron diffraction. This latter project is also supported by the Materials Development Branch of the Wright Patterson Air Force Base, Dayton, OH.

Professor Dutta's research activities focus on two different areas. The first area comprises analytical and experimental studies of the thermo-mechanical behavior of metal-matrix composites, including elevated temperature creep and thermal cycling response and matrix aging characteristics. The second area consists of studies of adhesion and residual stresses in thin films on ceramic and semi-conductor substrates for electronic packaging applications. In the area of adhesion, he has recently developed a new test for measurement of the adhesive strength of interfaces, which he is currently applying to a wide variety of film-substrate systems including gold-aluminum nitride and diamond-silicon. The program has been supported in the past by the Naval Surface Warfare Center-Crane Division, the Naval Air Warfare Center-Aircraft Division (Indianapolis), and NCCOSCRDT&E Division (NRaD). He is also investigating the metallization of diamond films for electronics applications with support from NSWC-Crane Division.

SURFACESHIP COMBAT SURVIVABILITY
C.N. Calvano, Associate Professor
Department of Mechanical Engineering
Sponsor and Funding: Naval Sea Systems Command

OBJECTIVE: Conduct literature searches and personnel contacts to locate both historical and current materials to permit development of a survey of combat survivability of surface warships. Begin the development of a database of such information to support further research into methods of improving total warship survivability.

SUMMARY: Numerous documents and records dealing with incidents of warship damage exist. A search of the NPS library and liaison with cognizant Navy experts at the Carderock Division of the Naval Surface Warfare Center and the Naval Sea Systems Command have resulted in the obtaining of several hundred potentially relevant documents. A complete set of World War II after-action damage reports has been obtained. Ultimately, these resources will be examined for information concerning damage mechanisms experienced as well as

design features incorporated in warships to minimize and avoid damage. The references will form a major basis for research which will describe survivability principles and factors affecting it as well as address the incorporation of survivability discipline in the warship design process. A database for summaries of information in the references was created, with approximately 200 of the references being catalogued to date.

OTHER: A two hour module on Designing for Warship Survivability has been introduced into NPS course TS3002, and is based, in part, on information gathered as part of this project.

DOD KEY TECHNOLOGY AREA: Other.

KEYWORDS: Combat Survivability, Warship Effectiveness, Warship Design.

STRUCTURAL DYNAMICS OF THE PHALANX CLOSE-IN WEAPONS SYSTEM

W. Colson, Professor

J.H. Gordis, Assistant Professor

Department of Mechanical Engineering

Sponsor and Funding: Naval Surface Weapons Center

OBJECTIVE: The goal of this project was to understand the dynamics of the Phalanx CWIS gun, with the intent of predicting and subsequently correcting the unacceptable round dispersion exhibited in test firings.

OBJECTIVE: The unacceptable dispersion of rounds exhibited in test firings of the Phalanx CWIS motivated the study of the structural dynamics of the gun. A detailed finite element model of the gun was built, based on design input from the gun's manufacturer and from inspection of an actual gun. The model allowed the calculation of the normal modes of vibration for the nonrotating gun, and transient dynamic response to simulated round firing (75 Hz. firing rate) was calculated. The finite element model allowed, for the first time in the gun's 30 year engineering history, the diagnosis of the dynamics of the breech assembly support in bearings, inside the gun housing. The calculated normal mode shapes provided valuable insight into possible structural mechanisms leading to round dispersion. In

fact, the finite element analysis results identified the bearings as likely causes of round dispersion due to the flexibility associated with the bearing load paths.

CONFERENCE PRESENTATION: Results were presented at a joint Navy/Industry Phalanx Design Review meeting.

THESES DIRECTED: Macneil, Donald, P., "Normal Modes of Oscillation of the Vulcan Phalanx Close-In Weapon System," Master's Thesis, June 1993.

Peterschmidt, John C., "Normal Modes of Vibration of the Phalanx Gun," Master's Thesis, June 1993.

OTHER: This phase of the project received letters of "Recognition of Excellence," from the Naval Surface Warfare Center, Port Hueneme and Dahlgren Divisions.

DOD KEY TECHNOLOGY AREA: Other.

KEYWORDS: Structural Dynamics, Phalanx, Vulcan, CWIS.

T56-A-427 ENGINE FUEL NOZZLE MODIFICATION

R. Crooks, Adjunct Professor

Department of Mechanical Engineering

**Sponsor and Funding: Naval Air Warfare Aircraft Division,
Patuxent River, MD**

OBJECTIVE: The goal of this study was to evaluate means of preventing the blockage in fuel nozzles due to coking of JP-5 fuel which occurs at temperatures above 300°F. This project was initiated in 1991 and is to be continued in 1994.

SUMMARY: Operational effectiveness of the T56-A-427 engine used in EC-2C+ has been adversely affected by coking of JP-5 in fuel nozzles during thermal soakback after shutdown. The coking occurs as oxidized fuel adheres to the stainless steel, eventually blocking fuel nozzle passages. Preliminary efforts focussed on assessment of coking parameters and design of a system to evaluate modified nozzle surfaces. It was determined that the fuel contributing to blockage is approximately 1 ml per cycle. Measurable blockage is observed after 30 cycles, with removing and cleaning necessary as early as 100 cycles vs. the design requirement of 3000 cycles. During 1993 we used a computer data acquisition and control system to simulate thermal cycle conditions at the fuel nozzle swirl plate, where blockage occurs. In the

test apparatus 1 ml of fuel is injected into a chamber at room temperature. One end of the chamber has a provision for attachment of samples which serve as experimental swirl plates, and heating elements are clamped to the outside of the chamber. The fuel in the chamber is heated to temperatures and at rates to match the conditions observed at the PAX River Telemetry Center, during evaluation of soakback in the T-56-A-427 engine of the E-2C+. The thermal exposure is followed by a purge. These three stages represent one cycle. We collaborated with commercial manufacturers of non-stick coatings during 1993, and began evaluation of a coating specially developed by General Electric for improved coking resistance.

OTHER: Results and program plans were reviewed during an on-site meeting with representatives of Naval Air Systems Command and NAWC, PAX River.

DOD KEY TECHNOLOGY AREA: Materials and Processes.

KEYWORDS: Coatings, Fuel, Engine.

ANALYSIS OF THRUST VECTOR (TVC) SYSTEM

M. Driels, Professor

Department of Mechanical Engineering

Sponsor and Funding: Naval Postgraduate School

OBJECTIVE: This work was to consolidate earlier, reimbursable funded studies to determine convective heat transfer coefficients for TVC control vanes. Identification of such coefficients from small scale (25% full size) tests, which may then be scaled up to full size, could offer considerable savings in experimental test and evaluation programs.

SUMMARY: The research develops a computer based model that would allow for the determination of transient thermal response characteristics of jet vanes of any size. The model used a thermal lumped parameter approach, considering only the conductive and convective heat transfer properties. A constrained optimizer was used to adjust the unknown variables in the model until an adequate match was achieved between the calculated temperatures from the energy balance equations, and the experimental values obtained from test firings of rocket motors.

The full scale modeling results were compared to those from full scale in an attempt to determine the applicability of scaling 25% tests to full scale. It was determined that

the small scale vanes did not provide an accurate representation of the heat transfer process in larger scale vanes, although the large scale model did provide an accurate representation of the heat transfer process.

OTHER: Parker, A., Driels, M., and Danielson, D., "Scale Effects on the Identification of Convective Heat Transfer Coefficients for Thrust Vector Control Vanes," Transactions AIAA, in review.

CONFERENCE PRESENTATIONS: Driels, M. and Danielson, D., "Testing and Analysis of Heat Transfer in Materials Exposed to Non-Metallized HTPB Propellant," 1992 JANNAF Rocket Nozzle Technology Sub-Committee Meeting, Sunnyvale, CA, December 1992.

THESIS DIRECTED: Parker, A., LCDR, USN, "Heat Transfer Parametric System Identification," Master's Thesis, June 1993.

DOD KEY TECHNOLOGY AREA: Materials and Processes, Propulsion and Energy.

KEYWORDS: Thrust Vector Control, Jet Vane, STARS.

FORCE OVERRIDE RATE CONTROL FOR REMOTE MANIPULATION

M. Driels, Professor

Department of Mechanical Engineering

Sponsor and Funding: NASA, Johnson Space Center

OBJECTIVE: This work is directed towards the design of a force control system for manipulating remote objects, which will overlay a currently installed rate control system, such as may be found on the Shuttle (STS) remote manipulator system (RMS). Two aspects of the problem were studied: (1) the design of a novel force transducer, and (2) the implementation of a 3 DOF force control system.

SUMMARY: The first part of the work discusses the design, construction and calibration of two force/torque transducer for use in a force control override of a rate control system. Pre-loaded force sensing resistors were simulated in a computer model to determine the number and location of sensors needed to resolve three forces and three moments, and corresponding levels of redundancy determined. Prototypes of a reduced order model sensing three forces and one moment were constructed and tested.

A force override control system was implemented on a PUMA 560 robot manipulator in three axes. The system consisted of the necessary sensors, hardware and software to

enable one person to operate the manipulator with unilateral force override of rate control. A comparison of theoretical and experimental responses to control inputs confirmed the effect of system gain on performance.

OTHER: Driels, M., "Design of a Rate and Force Control Scheme for Robot Manipulators," Transactions in ASME Journal of Mechanical Design, in review.

CONFERENCE PRESENTATION: Driels, M., "Force Override Rate Control System Design," Space Operations, Applications and Research Symposium, NASA JSC, August 1993.

THESES DIRECTED: Ondry, D., LCDR, USN, "Three Axis Force Override Rate Control of a PUMA 560 Manipulator," Master's Thesis, March 1993.

Gunzel, C., LCDR, USN, "Designing a Force-Torque Transducer for a Force Override Rate Control System," Masters's Thesis, June 1993.

DOD KEY TECHNOLOGY AREA: Software, Sensors, Human-System Interface.

KEYWORDS: Sensors, Force Control, Robots, Manipulation.

IMPROVED TARGET ACQUISITION ALGORITHMS FOR JANUS (A)

M. Priels, Professor

Department of Mechanical Engineering

Sponsor and Funding: U.S. Army, TRADOC Monterey

OBJECTIVE: JANUS is a combat simulation program for armored vehicles and infantry, which uses a terrain data base where each topological element is a square of side 100 meters. To improve accuracy of combat engagements, a database of 1 meter resolution has been developed. The project's objective is to determine the effect of the higher resolution database on the target detection and acquisition algorithms.

SUMMARY: The research has enhanced the TRADOC Analysis Command's JANUS (A) simulation system's detection model by incorporating new algorithms and data that more closely approximate real world combat-target acquisition performance. Data includes that available from TEXCOM

Experimentation Center's Pegasus high resolution terrain and target replicator databases. The project follows the model-test paradigm: (1) target acquisition models for visual and sensor aided acquisition have been developed and incorporated into JANUS; (2) actual target acquisition performance data has been collated during IOTE of the Javalin system and used to test model precision and validity, and, based on these results (3) the models have been further enhanced to increase their real-world accuracy.

DOD KEY TECHNOLOGY AREA: Software, Computers, Human-System Interfaces.

KEYWORDS: Simulation, Synthetic Environments, Combat Models.

**MICROSTRUCTURE-PROPERTY-PROCESSING RELATIONSHIP IN
METAL MATRIX COMPOSITES**

**I. Dutta, Associate Professor
Department of Mechanical Engineering
Sponsor and Funding: Naval Postgraduate School
(NSWC-White Oak, DFR)**

OBJECTIVE: To investigate microstructural development in metal matrix composites and to determine the effect of CTE mismatch on the properties of MMCs from a mechanistic standpoint.

SUMMARY: The effect of reinforcement distributions and processing conditions on the early stages of precipitation in composite matrices (2014 Al and 6061 Al) has been studied. Residual stress evolution as a function of processing and its effect on mechanical properties under monotonic loading and thermal cycling conditions have been investigated for both discontinuously and continuously reinforced aluminum-matrix composites. Mechanical property development as a function of processing history has also been evaluated. The importance of this project to the Navy and the scientific community lies in proper design of thermo-mechanical treatments to optimize thermo-mechanical properties in these materials.

PUBLICATIONS: Dutta, I., Sims, J.D., and Seigenthaler, D.M., "An Analytical Study of Residual Stress Effects on Uniaxial Deformation of Whisker Reinforced Metal-Matrix Composites," Acta Metallurgica et Materialia, Vol. 41, p. 885, 1993.

Dutta, I., Mitra, S., and Wiest, A.D., "Some Effects of Thermal Residual Stresses on the Strain Response of Graphite-Aluminum Composites during Thermal Cycling in Residual Stresses in Composites-Measurement, Modeling and Effect on Thermo-Mechanical Properties," in Proceedings of the 122nd TMS-AIME Annual Meeting, pp. 273-292, 1993.

Dutta, I., Harper, C.P., and Dutta, G., "Role of Al_2O_3 Particulate Reinforcement Composites," Metallic Transactions A, accepted.

OTHER: Dutta, I., Divecha, A.P. and Karmarkar, S.D., "Processing, Microstructure and Properties of Centrifugally Cast Al-SiCp Composites," in preparation for Advanced Materials and Processes.

THESIS DIRECTED: Muller, K.A., "Effect of Post-Fabrication Processing on the Tensile Properties of Centrifugally Cast SiC Particulate Reinforced Aluminum Composites," Master's Thesis, September 1993.

DOD KEY TECHNOLOGY AREA: Materials and Processes.

KEYWORDS: Composites, Processing, Mechanical Properties, Aging, Microstructure, Residual Stresses.

**CHARACTERIZATION OF ALUMINUM NITRIDE SUBSTRATES AND
THIN FILM-ALUMINUM NITRIDE INTERFACES FOR ELECTRONIC
PACKAGING APPLICATIONS**

I. Dutta, Assistant Professor

Department of Mechanical Engineering

Sponsor and Funding: Naval Weapons Support Center, Crane

Naval Air Warfare Center, Indianapolis

NCCOSC-RDT&E Division, San Diego

OBJECTIVE: To correlate processing, microstructure and properties in aluminum nitride substrates and substrate-coating interfaces.

SUMMARY: The sintering kinetics in liquid phase sintered aluminum nitride bulk pieces have been investigated to optimize processing parameters with respect to resultant microstructural changes and thermal conductivity. A mechanical test to measure adhesion between coatings and ceramic substrates is being developed, including both theoretical and experimental approaches. Residual stress generation in metallizations on AlN is being investigated via X-ray diffraction techniques function of process parameters. The focus is to optimize residual stresses in thin film metallizations and their adhesion to the ceramic substrates for electronic packaging applications.

PUBLICATIONS: Dutta, I., Mitra, S., and Cooper, J.H., "Process-Dependence of Microstructure and Properties of Sintered Aluminum Nitride Substrate Materials for Electronic Packaging Materials Science," in Proceedings of the Mat. Res. Symposium, Vol. 264, p. 395, 1992.

Dutta, I., Lascurain, D., and Secor, E.D., "A Constant Depth Scratch Test for the Measurement of Adhesion at Film-Substrate Interfaces," Materials

Week ' 93, in Proceedings of the Joint TMS/ASM Fall Meeting, Pittsburgh, October 1993.

PATENT: Dutta, I. and Lascurain, D., "A Constant-Depth Scratch Test for the Quantification of Interfacial Shear Strengths," Patent Application #NC75,747, filed August 1993.

THESES DIRECTED: Lascurain, D., "Development of a Scratch Test Apparatus to Evaluate Interfacial Adhesion at Metallizations on Ceramic Substrates," Master's Thesis, expected March 1994.

Sector, D., "Evaluation of the Shear Strength of Metallization-Substrate Interfaces by Constant-Depth Scratch Testing," Master's Thesis, December 1993.

OTHER: Mitra, S., Dutta, G., and Dutta, I., "Effect of Processing Conditions on the Microstructure and Properties of Dense Aluminum Nitride Sintered with Y₂O₃ Dopants," Journal of America Ceram. Society, in review.

DOD KEY TECHNOLOGY AREA: Materials and Processes.

KEYWORDS: Scratch test, Interfacial adhesion, Metallizations, Coatings, Thin Films, Ceramic Substrates, Residual Stresses, Electronics Packaging.

**A COMBINATIVE METHOD FOR THE ACCURATE MEASUREMENT OF
STRUCTURE FACTORS AND CHARGE DENSITIES OF INTERMETALLIC ALLOYS**

A.G. Fox, Associate Professor

Department of Mechanical Engineering

**Sponsors and Funding: Department of Energy and
Naval Air Development Center**

OBJECTIVE: To accurately measure the low-angle structure factors of elements and intermetallic alloys by various diffraction methods so that their electronic bonding mechanisms can be investigated.

SUMMARY: A knowledge of the distribution of bonding electrons in solids can give important information about their physical properties. One way to gain such knowledge is to accurately measure the low-angle structure factors by some means, and then use these to generate maps of the electron charge distributions. In the present work electron diffraction has been used to measure the low-angle structure factors of SnAl and an electron charge distribution has been generated for this alloy and important bonding information has emerged. During 1991 x-ray diffraction work commenced on the TiAl system and in 1992 continued so that accurate values of the lattice parameters and Debye-Waller factor of TiAl were obtained. During the last quarter of 1992 and during 1993 electron diffraction measurements of the low-angle structure factors of TiAl were made on the 1.5 MeV high voltage electron microscope (HVEM) at the University of California, Berkeley and on the 3.0 MeV HVEM at CEMES/LOE du CRNS, Toulouse, France. These results have now been analyzed and publications are now beginning to emerge as shown below.

PUBLICATIONS: Fox, A.G., "The Electron Charge Distribution of Chromium," Philosophical Magazine B,

Vol. 68, pp. 275-283, 1993.

Fox, A.G., "Is it Feasible to Determine the Bonding Charge Density of TiAl Through Structure Factor Measurements," Philosophical Magazine Letters, Vol. 68, pp. 29-37, 1993.

Fox, A.G., "Electron Diffraction Studies Reveal Bonding Mechanisms in Many Crystalline Solids," Research Highlight published by the Lawrence Berkeley Laboratory, University of California, Berkeley, 1993.

CONFERENCE PRESENTATIONS: Fox, A.G., Lu, Z.-W., Zunger, A., and de Fontaine, D., "Structure Factors and Charge Density of TiAl : a Comparison of Ab Initio Local Density Calculations with Data from Electron Diffraction Experiments," Electron Microscopy and Analysis Group '93 Meeting, Liverpool, England, 14-17 September 1993.

Fox, A.G., "Bonding Charge Densities Measured by Electron Diffraction," Centre D'Elaboration de Materiaux et Detudes Structurales, Laboratoire D'Optique Electronique du Centre National de la Recherche Scientifique, Toulouse, France, 25 June 1993.

Fox, A.G., "The Bonding Charge Density of TiAl ," Naval Air Development Center, Warminster, PA, 9 August 1993.

DOD KEY TECHNOLOGY AREA: Materials and Processes.

KEYWORDS: Electron Diffraction,

Change Densities, Intermetallic Alloys.

MICROSTRUCTURES AND MECHANICAL PROPERTIES OF HIGH-STRENGTH, LOW-ALLOY (HSLA) STEELS AND THEIR WELDMENTS

A.G. Fox, Associate Professor
Department of Mechanical Engineering
Sponsors and Funding: Annapolis Detachment,
Carderock Division of the Naval Surface Warfare Center, MD

OBJECTIVE: To investigate the microstructure and mechanical properties of HY and HSLA 80-130 series steels and their weldments to evaluate new weld consumables and parent steels for Naval shipbuilding applications.

SUMMARY: In recent years the U.S. Navy has been replacing the HY80-100 series of high strength alloy steels with their high strength, low-alloy (HSLA) equivalents. This is being done because the stringent weld preheat requirements associated with the HY steels are not necessary for the HSLA series. So, despite the higher manufacturing costs of high-strength, low-alloy steels, the U.S. Navy should make significant savings by changing over to HSLA or ultra low carbon bainitic (ULCB) steels for ship and submarine construction. In addition, the Navy's stringent requirement that weld metal have the same strength as the base plate presents an interesting challenge in weld wire development for both HSLA and HY steels. This project aims to support these objectives with fundamental physical metallurgy studies at NPS. This project was very successful with three Masters Theses completed in 1992, one publication and one NPS Technical Report completed and one conference proceeding presented. In addition, Professor S.D. Bhole of Regina University, Saskatchewan, Canada

visited NPS for six months during 1993 to assist with this project.

PUBLICATION: Bhole, S.D. and Fox, A.G., "Some Interesting Microstructures in very Low Carbon High Manganese Microalloyed Steels," Scripta Metallurgica, Vol. 29, pp. 1391-1396, 1993.

Fox, A.G. and Bhole, S.D., "The Influence of TIG Welding Thermal Cycles on HSLA-100 Steel Plate," NPS Technical Report NPS-ME-93-008, November 1993.

CONFERENCE PRESENTATION: Bhole, S.D. and Fox, A.G., "The Influence of TIG Welding Thermal Cycles on HSLA-100 Steel Plate," 95th Canadian Institute of Materials Annual Meeting, Calgary, Alberta, Canada, 9-12 May 1993.

THESES DIRECTED: Butler, D.E., LT, USN, "The Quantitative Microstructural Characterization of Multipass TIG ULCB Weldments and Correlation with Mechanical Properties," Master's Thesis, September 1993.

Seraiva, R.A., LT, USN, "The Study of Single-Pass GMA Welds with Difference Cover Gas Composition on HSLA-100 Steel," Master's Thesis, September 1993.

Kettell, K.W., LT, USN, "Correlation of Flux Composition and Inclusion

Characteristics with Submerged Arc Weld Metal Properties in HY-100 Steel," Mechanical Engineer's and Master's Thesis, September 1993.

DOD KEY TECHNOLOGY AREA: Other.

KEYWORDS: Welding of High Strength Steels.

**X-RAY DIFFRACTION AND ELECTRON MICROSCOPE STUDIES OF YSZ
CERAMIC COATINGS FOR GAS TURBINE APPLICATIONS**

A.G. Fox, Associate Professor

Department of Mechanical Engineering

Sponsors and Funding: Annapolis Detachment,

Carderock Division of the Naval Surface Warfare Center, MD

OBJECTIVE: To investigate the degradation of yttria stabilized zirconia ceramic thermal barrier coatings when exposed to vanadium pentoxide.

SUMMARY: The U.S. Navy has an ongoing program of research into yttria stabilized zirconia (YSZ) ceramic coatings for gas turbine blades. Although very successful when used with high quality fuels, YSZs can deteriorate when cheaper fuels are used, particularly when vanadium is present in the fuel as an impurity when degradation of YSZ occurs so that significant reduction in turbine blade lifetimes results. The object of the present work is to investigate the diffusion of V_2O_5 into a YSZ of composition ZrO_2 -9.4 mol.% Y_2O_3 by X-ray diffraction and electron microscopy in order to try and understand why vanadium in fuels degrades YSZs. During 1992 experiments at NPS were performed which indicated that V_2O_5 reacts preferentially with Y_2O_3 to form YVO_4 but in regions well away from the diffusion interface between the V_2O_5 and the YSZ where all the yttria is apparently 'tied up' as YVO_4 the

vanadia can react with the free zirconia now available to form the compound ZrV_2O_7 . Both YVO_4 and ZrV_2O_7 are extremely brittle and thus the YSZ rapidly degrades on exposure to vanadia. During 1993 we investigated the effect of ternary alumina 'composite' additions to the YSZ to see if this could improve its resistance to corrosion attack by V_2O_5 . This work has shown that alumina additions to YSZ are almost completely inert when exposed to vanadia.

THESIS DIRECTED: Krestos, D.M., LT, USN, "An X-Ray Diffraction Study of alpha-aluminum additions to Yttria Stabilized Zirconia Thermal Barrier Coatings Subject to Destabilizing Vanadia Exposure," Master's Thesis, September 1993.

OTHER: This is a new project in FYs 92/3 and so far no publications or conference proceedings have resulted.

DOD KEY TECHNOLOGY AREA: Materials and Processes.

KEYWORDS: Electron Microscopy, X-Ray Diffraction, Yttria Stabilized

Zirconia Ceramic Coatings.

**MICROSTRUCTURAL STUDIES OF SILICON FIBER REINFORCED GLASS-
CERAMIC COMPOSITES FOR GAS TURBINE APPLICATIONS**

A.G. Fox, Associate Professor

Department of Mechanical Engineering

Sponsor and Funding: Naval Air Warfare Center

OBJECTIVE: To investigate the hot corrosion of silicon fiber reinforced glass-ceramic matrix composites.

SUMMARY: The U.S. Navy has an ongoing program of research into silicon fiber reinforced glass-ceramic matrix composites (CMCs) which have many potential uses for gas turbine components. The high strength, toughness and resistance to high temperatures and low density of CMCs could allow a considerable increase in gas turbine engine efficiency if they could be used to replace heavy metallic parts. Unfortunately Naval aircraft operating environment is very severe and any CMC components developed must be resistant to high temperature environments containing salt and aviation fuel which may be rich in sulfur. This work proposes to use electron microscopy and x-ray diffraction to elucidate the mechanisms of hot salt corrosion in

lithium, calcium, magnesium and barium-magnesium aluminosilicates reinforced with silicon carbide fibers. The results of this work may help determine which CMCs are suitable for Naval applications.

THESIS DIRECTED: Madia, L.C., LT, USN, "Sodium Sulfate Corrosion of Silicon Fiber Reinforced Lithium Aluminosilicate Glass-Ceramic Matrix Composites," Master's Thesis, December 1993.

OTHER: This is a new project in FY 93 and so far no publications or conference proceedings have resulted.

DOD KEY TECHNOLOGY AREA: Materials and Processes.

KEYWORDS: Glass-Ceramic Composites, Gas Turbine Engines.

**SHIPBOARD SYSTEMS SURVIVABILITY: DYNAMIC DESIGN ANALYSIS AND
TESTING METHODS AND LIVE FIRE TEST SIMULATION**

J.H. Gordis, Assistant Professor

Y.S. Shin, Professor

Department of Mechanical Engineering

Sponsor and Funding: Naval Sea Systems Command

OBJECTIVE: This continuing project is concerned with the development of computational methods for the component-based structural dynamic analysis of shipboard mast/antennae systems. The goal is to provide the computational tools to allow weapons-effect survivability to be "designed in" to new mast/antennae systems, and to allow the enhancement of survivability for existing mast/antennae systems.

SUMMARY: Shipboard combat systems are subjected to damaging transient forces due to weapons effects such as underwater explosion (UNDEX). In order to improve the UNDEX survivability of combat systems such as the mast/antenna structural sy-

stem, this project is concerned with the development of modern computational techniques for the prediction of transient response. A class of substructuring methods, known as component mode synthesis, are examined and specialized to the mast/antenna survivability enhancement problem. The computationally efficient and component-based approach of component mode synthesis is consistent with the long term goal of developing a specialized computer-aided design tool for mast/antenna systems.

DOD KEY TECHNOLOGY AREA: Other.

KEYWORDS: Structural Dynamics, Survivability, Mast, Antenna.

**SUBMARINE MACHINERY CRADLE: STRUCTURAL DYNAMIC DESIGN AND
ANALYSIS TECHNIQUES**

J.H. Gordis, Assistant Professor

A.J. Healey, Professor

Department of Mechanical Engineering

Sponsor and Funding: Program Executive Office - Submarines

OBJECTIVE: This project was concerned with the development and specialization of a state-of-the-art frequency domain method for the structural dynamic analysis of cradle structures. Additionally, rule-based design optimization techniques are explored for use in conjunction with the frequency domain re-analysis method.

SUMMARY: The effectiveness and survivability of submarines is dependent on the minimization of the propagation of acoustic energy to the ocean, and on the degree of isolation from external shock waves provided for critical submarine internal systems. In support of these goals, an advanced machinery cradle has been proposed which will provide bi-

direction isolation of internal systems. The development of computational tools for the efficient design of the cradle is the goal of this project. Frequency domain structural synthesis is a highly efficient means of performing static and complex dynamic structural design re-analysis. The project demonstrated the effectiveness of the frequency domain technique in conjunction with the application of an expert system rule-based design methodology.

DOD KEY TECHNOLOGY AREA: Other.

KEYWORDS: Structural Dynamics,
Frequency Domain, Isolation,
Submarine.

FREQUENCY DOMAIN METHODS IN STRUCTURAL SYNTHESIS AND IDENTIFICATION

J.H. Gordis, Assistant Professor
Department of Mechanical Engineering
Sponsor and Funding: Naval Postgraduate School

OBJECTIVE: This project is concerned with the theoretical development of a frequency domain theory for structural system identification. The theory is based on a previously developed theory for frequency domain structural synthesis.

SUMMARY: This research concerns the development and validation through practical application of a frequency domain theory for structural system identification and structural damage detection. The frequency domain theory avoids fundamental limitations associated with modal-based methods by the elimination of modal parameter estimation and modal truncation errors, and by the direct treatment of the errors associated with instrumenting the test specimen with a finite number of response measurement transducers. Under development is the necessary theory for the practical identification of an impedance error spectra for a linear math model of a dynamic system and the subsequent decomposition of the impedance error spectra into the constituent error spectra of mass, stiffness, and (non-proportional) damping. Focusing on spatially incomplete identification, the research is investigating the localization of model errors and the relationship between the error spectra identified from spatially incomplete test data and the "true" parameter errors in the original, unreduced analytic model. The research will introduce non-traditional physical coordinate model

reduction methods as well as traditional optimization techniques to cope with the limited amount of data typically generated in a vibration test. Experimental studies with simple yet representative structures are underway.

PUBLICATIONS: Gordis, J.H., "Spatial, Frequency Domain Updating of Linear, Structural Dynamic Models," in Proceedings of the 34th AIAA/ASME/ASCE/AHS/ACS Structures, Structural Dynamics, and Materials Conference, April 1993.

Gordis, J.H., "An Exact Formulation for Structural Dynamic Model Error Localization," in Proceedings of the 11th International Modal Analysis Conference, Orlando, FL, 1993.

Gordis, J.H., "A Frequency Domain Theory for Structural Identification," Journal of the American Helicopter Society, Vol. 38, No. 2, April 1993.

CONFERENCE PRESENTATION: Gordis, J.H., "Spatial, Frequency Domain Updating of Linear, Structural Dynamic Models," 34th AIAA/ASME/ASCE/AHS/ACS Structures, Structural Dynamics, and Materials Conference, April 1993.

DOD KEY TECHNOLOGY AREA: Other.

KEYWORDS: Structural Dynamics, Frequency Domain, Isolation, Submarine.

AUTONOMOUS UNDERWATER VEHICLES

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Department of Electrical Computer Engineering
S.H. Kwak, Research Associate Professor
Department of Computer Science
D. Brutzman, Instructor
Department of Operations Research
Sponsor and Funding: Naval Postgraduate School

OBJECTIVE: As the use of Remotely Operated Underwater Vehicles becomes more widespread and their tasking more complex in deeper waters, there is a need to free the vehicle from the power and signal umbilical, and to increase the level of autonomy and the precision of the motion control of these underwater robots in performing mine hunting and ocean monitoring tasks.

SUMMARY: This year, the Rational Behavior Model software architecture was initially developed in previous years and distinguished by the recognition of three levels of control each based on a different programming paradigm. Further development of this architecture this year has led to the funding of an expanded study for application to unmanned underwater vehicles in general by the NSF. We have now succeeded in converting the earlier concept to a version that runs in the vehicle computer as part of a virtual reality system in the simulation laboratory, and will be tested in the upcoming months in an open water demonstration using the NPS AUV II vehicle. Also, during FY93, the NPS AUV II has under gone extensive modification to include imaging sonars - TRITECH ST 725 and ST 1000 units, full implementation of the

cross body thrusters, including detailed modeling and analysis of thruster performance under static and dynamic conditions.

PUBLICATIONS: Healey, A.J. and Lienard, D., "Multivariable Sliding Mode Control for Autonomous Diving and Steering of Unmanned Underwater Vehicles," IEEE Journal of Oceanic Engineering, Vol. 18, No. 3, pp. 327-339, July 1993.

Papoulias, F.A., "Loss of Stability of Guidance and Control Laws for Autonomous Vehicles," Dynamics and Stability of Systems, Vol. 8, No. 1, 1993.

Healey, A.J., "Towards an Automatic Health Monitor for Autonomous Underwater Vehicle using Parameter Identification," in Proceedings of the American Control Conference, San Francisco, CA, 2-4 June 1993.

Papoulias, F.A., "Dynamics and Bifurcation for Vehicle Path Keeping in the Dive Plane," Journal of Ship Research, Vol. 37, No. 2, June 1993.

Papoulias, F.A., "On the Nonlinear Dynamics of Pursuit Guidance for Marine Vehicles," Journal of Ship Research, to appear 1993.

Papoulias, F.A., "Cross-Track Error and Proportional Turning Rate Guidance of Marine Vehicles," Journal of Ship Research, to appear 1993.

Brutzman, D., "Beyond Intelligent Vacuum Cleaners," in Proceedings of the AAAI Symposium on Applications of Artificial Intelligence for Instantiating Real World Agents, pp. 23-25, Raleigh, NC, 22-24 October 1993.

Brynes, R., Kwak, S.H., McGhee, R., Healey, A.J., and Nelson, M., "Rational Behavior Model: An Implemented Tri Level Multilingual Software Architecture for Control of Autonomous Vehicles," in Proceedings of the 8th UUST, pp. 160-179, the University of New Hampshire, Durham, NH, 27-29 September 1993.

Kwak, S.H., Stevens, C.D., Clynch, J.R., McGhee, R.B., and Whalen, R.H., "An Experimental Investigation of GPS/INS Integration for Small AUV Navigation," in Proceedings of the 8th UUST, the University of New Hampshire, Durham, NH, pp. 239-252, 27-29 September 1993.

THESES DIRECTED: Blank, R.A., "A Structured Programming Approach to Complex AUV Mission Control," Master's Thesis, September 1993.

Cottle, D., "Mine Avoidance and Alocalization for Underwater Vehicles

using Continuous Curvature Path Generation and Non-Linear Tracking," Master's Thesis, September 1993.

Cody, S.E., "An Experimental Study of the Response of Small Tunnel Thrusters to Triangular and Square Wave Inputs," Master's Thesis, December 1992, (available through NTIS).

Brown, J., "Four Quadrant Dynamic Model of the AUV II Thruster," Master's Thesis, September 1993, (available through NTIS).

Thornton, F.P.B., "A Concurrent Object - Based Implementation for the Tactical Level of the RBM," Master's Thesis, September 1993, (available through NTIS).

Scholz, T., "The State Transition Diagram with Path Priority and it's Applications," Master's Thesis, September 1993.

DOD KEY TECHNOLOGY AREA: Design Automation.

KEYWORDS: Underwater Robotics, Intelligent Systems, Control.

**DEVELOPMENT OF AN UNDERWATER ROBOT SIMULATION GRAPHICS
TOOL IN SUPPORT OF EXPLOSIVE ORDNANCE DISPOSAL**

A.J. Healey, Professor

Department of Mechanical Engineering

Sponsor and Funding: NAVEODTECHCEN, Indian Head, MD

OBJECTIVE: This work was a small effort to build a graphics based simulator for the visualization of the controlled motion of the underwater Remotely Operated Vehicle (ROV) - the Deep Sea Ventures 'PHANTOM'.

SUMMARY: The simulator code runs on an SGI workstation and was used by Lockheed Corp. in their work with the same sponsor. No publications are

expected from this work at this stage, although it is leading to larger programs in Simulation Based Design and Scientific Visualization.

DOD KEY TECHNOLOGY AREA: Design Automation.

KEYWORDS: Robotics, Simulation and Modeling, Mine Warfare.

**SONAR SIGNAL ACQUISITION AND PROCESSING FOR IDENTIFICATION AND
CLASSIFICATION OF SHIP HULL FOULING**

A.J. Healey, Professor

R. Mukherjee, Associate Professor

Department of Mechanical Engineering

Sponsor and Funding: Naval Surface Warfare Center,

Annapolis Detachment, Code 2752, Annapolis, MD 21402-5067

OBJECTIVE: This work has involved the use of the Naval Postgraduate School's TRITECH ST 725 high frequency mechanically scanned sonar system to acquire sonar images of simulated surface roughness on an aluminum plate. Signal post processing for such image data is reviewed, and processed data is analyzed and compared to the known roughness locations on the plate.

The simulated roughness (a pattern of one half inch steel nuts) is used in a preliminary experiment as part of the development of a sonar detection system for marine growth on ship hull plating. Such a sonar system will be an integral part of any Ship Hull Autonomous Cleaning Robot (SHACR).

SUMMARY: Contained in the report of this work is a description of the experimental arrangement, typical sonar returns, a summary of image processing techniques appropriate to this problem and results of processed data as compared to the known locations of the simulated roughness.

The algorithms presented here will ultimately lead to a real time processing capability for the specification of location, extent, roughness level, as needed for the automatic direction of a SHACR's motion control and cleaning systems.

PUBLICATION: Healey, A.J. and Mukherjee, R., "Sonar Signal Acquisition and Processing for Identification and Classification of Ship Hull Fouling," NPS Technical Report NPS-93-ME-007, 30 September 1993.

DOD KEY TECHNOLOGY AREA: Design Automation.

KEYWORDS: Underwater Robotics, Acoustic Imaging.

THERMAL MODELING IN SUPPORT OF ALISS
(Advanced Lightweight Influence Sweep System)

M.D. Kelleher, Professor

Department of Mechanical Engineering

**Sponsor and Funding: Annapolis Detachment, Carderock Division,
Naval Surface Warfare Center**

OBJECTIVE: The objective of this project is to perform thermal modeling studies of the superconducting magnet systems to be used in the Advanced Lightweight Influence Sweep System (ALISS). The thermal models will be used to evaluate various proposed designs for the support systems and electrical interfaces to be used with the superconducting magnets in ALISS.

SUMMARY: This is a new thermal modeling research project in support of the ALISS Program. ALISS is an Advanced Technology Demonstration Program to validate the feasibility of using superconducting technology for systems used to sweep magnetic influence mines. Mine countermeasures (MCM) are conducted to clear or map a safe passage through anti-invasion mine fields. The Navy has already identified critical deficiencies in the capability to conduct rapid MCM in support of a "surface forcible entry." Characteristics of MCM systems currently used to counter magnetic influence mines restrict sweep rates, limit the ability to accurately simulate a ship's magnetic signature, and require a minimum water depth. Advances in superconducting technology over the last twenty years have significantly increased the feasibility of using superconducting mine countermeasures (SCMCM) for magnetic influence mines. The use of superconducting magnets for coastal minesweepers holds the potential for smaller, lighter, and more energy efficient systems. The Advanced Lightweight Influence Sweep System (ALISS) is an Advanced Technology

Demonstration project to validate the feasibility of superconducting technology is sweep magnetic influence mines. A standard method for achieving superconductivity is to use immersion in a liquid helium bath to achieve the required superconducting temperature. The use of liquid helium in a shipboard environment presents many problems in the production and handling of the required amounts of liquid helium. To avoid these problems it has been proposed to use conductively cooled superconducting magnets. One means of implementing this concept is to use a closed cycle device such as a Gifford-McMahon cryocooler. If such a system is to be used it is critical that the total heat budget for the system be understood. A thermal modeling effort of the proposed conductively cooled superconducting magnet system is being undertaken. All possible paths and heat transfer mechanisms for heat leakage will be considered. The magnets structural support systems, the electrical connections, the cryocooler connections as well as the surrounding insulation will be modeled. The thermal modeling will be implemented using standard computational software such as NISA. The objective of this effort will be to obtain a tool which will allow the identification and evaluation of the critical heat flow paths and an assessment of design modifications.

DOD KEY TECHNOLOGY AREA: Other.

KEYWORDS: Thermal Modeling,
Superconducting Magnets, Cryogenics.

STUDY OF INSTABILITY OF UNBALANCED, SANDWICH COMPOSITES

Y.W. Kwon, Associate Professor

Department of Mechanical Engineering

Sponsor and Funding: Naval Surface Warfare Center

OBJECTIVE: The goal of this project was to investigate stability of unbalanced, sandwich composite panels made of titanium and glass reinforced plastic skins and a honeycomb core. The failure loads and modes of the structure was studied using both experimental and analytical techniques.

SUMMARY: An unbalanced, sandwich composite structure consisting of TI 6AL-4V and GRP (Glass Reinforced Plastic) skins with a phenolic honeycomb core was being considered for construction of a surface ship mast which would enclose critical shipboard equipment. Stability of the structure was one of the major concerns in the design process. Both theoretical and experiment analyses were performed for the buckling instability of the composite panels of various sizes. The theoretical analysis took into account the bending strain energy of skin materials as well as core material shearing energy. Uniaxial compressive load experiments were conducted on eight unbalanced, sandwich composite beams simply supported on the loaded ends and the overall limit loads observed were within 10% of the theoretical predictions using the analytical model developed. Core shearing initiated quickly after load was

applied to a buckled specimen, and the specimen abruptly lost its load carrying capacity. Other possible modes of failure in sandwich structures were not observed. The residual compressive strengths of the sandwich beams, after the initial failure, were almost the same as their initial core shearing loads.

The ideal condition of simple support was very closely achieved by the described experimental design. No local damage was introduced by the end supports.

PUBLICATION: Kwon, Y.W., Murphy, M.C., and Castelli, V., "Buckling of Unbalanced, Sandwich Beams," Recent Advances in Structural Mechanics, PVP-Vol. 269, NE-Vol. 13, pp. 37-46, ASME, 1993.

THESIS DIRECTED: Murphy, M.C., "A Study of Structural Instability of Unbalanced, Sandwich Composites," Master's Thesis, June 1993.

OTHER: One paper has been submitted for publication in a journal. One paper is in preparation.

DOD KEY TECHNOLOGY AREA: Materials and Processes.

KEYWORDS: Composite, Sandwich Structure, Stability.

DEVELOPMENT OF A MODEL FOR DAMAGE ANALYSIS OF COMPOSITES

Y.W. Kwon, Associate Professor

Department of Mechanical Engineering

Sponsor and Funding: Naval Postgraduate School

OBJECTIVE: The goal of this project was to develop an analysis model and failure criteria to investigate damage modes and failure loads in laminated fibrous composite structures.

SUMMARY: A micromechanic model was developed for damage and failure analyses of fibrous composite structures. It was incorporated into a finite element analysis program for laminated composite structures. The micromechanical model used stresses and strains at the fiber and matrix level to determine the smeared composite stresses and strains. The damage and failure criteria were based on the fiber and matrix stresses, obtained from the micromechanical model, rather than smeared composite stresses.

Progress of damage, such as matrix cracking and fiber breakage, as well as ultimate failure loads were computed from the model and compared to experimental results. For examples, matrix cracking in ceramic composite plates, and damage progress and failure load of a graphite/epoxy composite plate with a hole were considered. In addition, off-axis strengths of various unidirectional composites were computed. The analytical results agreed very well with experimental results.

The current micro-mechanical model along with the failure criteria could provide the following important informations for study of failure and damage progress in fibrous layered composite structures: the damage types, damage progress, stress redistribution due to local damage,

and the ultimate failure load.

PUBLICATIONS: Kwon, Y.W., "Calculation of Effective Moduli of Fibrous Composites with Micro-Mechanical Damages," Composites Structures, Vol. 25, pp. 187-192, 1993.

Kwon, Y.W. and Sertunc, M., "Static and Dynamic Buckling of a Fiber Embedded in a Matrix with Interface Debonding," Journal of Pressure Vessel Technology, ASME Transactions, Vol. 115, pp. 297-301, August 1993.

Kwon, Y.W. and Christy, C., "An Efficient Finite Element Modeling of Dynamic Crack Propagation Using a Moving Node Element," accepted for publication in Structural Engineering and Mechanics.

Kwon, Y.W. and Berner, J.M., "Numerical Modeling of Stiffness Reduction Due to Transverse Cracking in Unidirectional Composites," Computational Engineering, in Proceedings of the First Pan-Pacific Conference on Computational Engineering, Seoul, Korea, Elsevier, pp. 3-8, November 1993.

Kwon, Y.W. and Babiloglu, E., "Numerical Analysis of Crack Propagation in Unidirectional Composite Plates," in Proceedings of the ASME Energy Technology Conference and Exhibition, Houston, TX, January 1993.

THESES DIRECTED: Christy, C.T., "Numerical Modeling of Dynamic Crack Propagation," Master's Thesis, June 1993.

Berner, J., "Finite Element Analysis of Damage in Fibrous Composites Using a Micromechanical Model," Master's Thesis, December 1993.

OTHER: Two papers have been submitted for journals.

DOD KEY TECHNOLOGY AREA: Materials and Processes.

KEYWORDS: Fibrous Composite, Failure Criteria, Damage Progress, Micromechanical Model.

GRAIN BOUNDARIES IN SUPERPLASTIC ALUMINUM

**T.R. McNelley, Professor
Department of Mechanical Engineering
Sponsor: Office of Naval Research
Funding: Naval Postgraduate School**

OBJECTIVE: The goal of this program is to study the role of grain boundaries in fine-grained, superplastic aluminum alloys and the development of such grain boundaries in thermomechanical processing of these materials.

SUMMARY: Two different mechanisms of microstructural refinement during the thermomechanical processing at 573K for Al-Mg alloys of high Mg content have been identified. With a brief interpass anneal grain boundaries developed via a twin chain mechanism. The use of a prolonged interpass anneal resulted in high angle boundaries associated with recrystallization and superplastic elongations in excess of 1000% during straining at a low temperature of 573K. Recrystallization via particle-stimulated nucleation (PSN) was attributed to the coarsening of precipitates during the prolonged interpass anneals. Boundaries of recrystallization nuclei were associated with a lattice of rotation of approximately 40° about $\langle 111 \rangle$. Similar processing studies for the commercial 2519 alloy indicated that the critical particle size for PSN is larger in the Al-Cu alloy.

PUBLICATIONS: McNelley, T.R., Crooks, R., Kalu, P.N., and Rogers, S.A., "Precipitation and Recrystallization During Processing of a Superplastic Al-10Mg-0.1Zr Alloy," Materials Science and Engineering, Vol. A166, pp. 135-144, 1993.

McNelley, T.R., Salama, A.A., and Kalu, P.N., "Constitutive Equations for the Behavior of Superplastic Al-Mg Alloys," in Advances in Superplasticity and Superplastic Forming, N. Chandra, H. Garmestani and R.E. Goforth, eds., The Metallurgical Society, Warrendale, PA, pp. 45-54, 1993.

CONFERENCE PRESENTATION: McNelley, T.R., Kalu, P.N., and Crooks, R., "Thermomechanical Processing and Grain Refinement for Superplasticity in Aluminum Alloys," Symposium on Light-Weight Alloys for Aerospace Applications, held in conjunction with the 122nd TMS Annual Meeting, Denver, CO, 23 February 1993.

THESES DIRECTED: Coleman, M.T., "The Use of the Backscattered Electron Imaging Mode to Assess the Effect of Fine Dispersions on Development of Superplastic Microstructures in Al-Mg Alloys," Master's Thesis, June 1993.

Zohorsky, P.J., "Study of Precipitation and Recrystallization in Al Alloy 2519 by Backscattered Electron Imaging Methods," Master's Thesis, September 1993.

DOD KEY TECHNOLOGY AREA: Materials and Processes.

KEYWORDS: Aluminum, Superplasticity, Recrystallization, Grain Boundaries, Thermomechanical Processing.

**THERMOMECHANICAL PROCESSING AND DUCTILITY ENHANCEMENT
OF DURALCAN COMPOSITE MATERIALS**

T.R. McNelley, Professor

Department of Mechanical Engineering

Sponsor and Funding: DURALCAN-USA, San Diego, CA

CDRA Agreement, May 1993

OBJECTIVE: The goal of this program is to obtain improved combination of strength, ductility and toughness in Al-based metal-matrix composite materials by thermomechanical processing.

SUMMARY: Discontinuously reinforced Al-Al₂O₃ composite materials have many attractive properties but lack adequate ductility and toughness for many applications. Dramatic improvements in composite ductibility have been attained in extruded 6061 Al-Al₂O₃ processed using methods designed to redistribute the Al₂O₃ particles as well as achieve a fully recrystallized matrix grain structure via particle-stimulated nucleation of recrystallization. Further improvements in ductility have been obtained with use of controlled heat treatments on processed material. Processing methods suitable for production of extruded materials have also been designed and evaluated.

PUBLICATION: McNelley, T.R. and Kalu, P.N., "Thermomechanical Processing and Ductility Enhancement of a 6061 Al-Al₂O₃ Metal Matrix Composite," Advanced Synthesis of Engineered Structural Materials, in Proceedings of the International

Conference, J.J. Moore, E.J. Lavernia and F.H. Froes (Eds), ASM International, Materials Park, OH, pp. 93-98, 1993.

THESES DIRECTED: Longenecker, F.W., "An Analysis of the Microstructure and Reinforcement Distribution of an Extruded, Particle-Reinforced Al-10 Vol. pct. Al₂O₃ Metal Matrix Composite," Master's Thesis, September 1993.

Hoyt, W.F., "The Effect of Thermomechanical Processing on Mechanical Properties of a cast 6061 Al-Al₂O₃ Metal Matrix Composite," Master's Thesis, December 1993.

OTHER: McNelley, T.R., "Thermomechanical Processing and Ductility Enhancement of Particulate-Reinforced Aluminum (PRA)," invited seminar, U.S. Army Research Laboratory, Watertown, MA, 6 December 1993.

DOD KEY TECHNOLOGY AREA: Materials and Processes.

KEYWORDS: Metal-Matrix Composites, Processing, Ductility, Particle Distribution, Grain Refinement.

**CONTINUOUS MEASUREMENT OF AGING USING EDDY CURRENT SENSORS
DURING HEAT TREATMENT OF PRECIPITATION HARDENING ALLOYS**

T.R. McNelley, Professor

Department of Mechanical Engineering

Sponsor: Naval Air Warfare Center, Warminster, PA

Funding: Naval Air Warfare Center

OBJECTIVE: The goal of this program is the development of sensors for the continuous measurement of the aging response during heat treatment of a precipitation hardening alloy. Intelligent processing requires such a sensor to monitor material response in real time and provide input to a controller.

SUMMARY: This research involved further development of a sensor systems for the continuous monitoring of the aging response of 7075 Aluminum alloy during intelligent heat treatment of the material. Intelligent processing requires sensors to monitor material response in real time. The feasibility of such a measurement using eddy current methods has been demonstrated. A sensor consisting of two spiral-wound probes and a bridge circuit with a bridge carrier amplifier was used to obtain data reflecting the changing

resistivity of 7075 Aluminum during isothermal aging. Mechanical property data were correlated with the resistivity data. Modification of the system to obtain data under non-isothermal conditions will facilitate control of complete heat treatment cycles. Also, sensors capable of operation at temperatures up to 500°C will be fabricated for applications involving higher temperature alloys.

THESIS DIRECTED: Mata, S.G., "Continuous Measurement of Aging Response in Aluminum Alloys by Eddy Current Methods," Master's Thesis, September 1993.

DOD KEY TECHNOLOGY AREA: Materials and Processes.

KEYWORDS: Intelligent Processing; Heat Treating; Aluminum Alloys.

ADVANCED GAS TURBINE SEALS

K.T. Millsaps, Jr., Assistant Professor
Department of Mechanical Engineering
Sponsor and Funding: Naval Postgraduate School
(Direct Funding, Research Initiation Program)

OBJECTIVE: To advance the state-of-the-art in gas turbines sealing technology.

SUMMARY: (1) The preliminary design of a 2-D test facility for measuring the flow in labyrinth seals has been completed. Several types of designs were considered and investigated. A detailed mechanical design with full machine drawings has been finished. Work on the facility test section, etc. will initiate when the low speed boundary layer tunnel is moved to Bldg. 230.

(2) Much of the previous work initiated at MIT for the author's Sc.D., both theoretical and experimental, on rotodynamic coefficients for labyrinth seals has been finished this year. This work resulted in three (3) conference papers and two (2) journal articles over the past year. The two major contributions to the archive literature are:

a. Damping coefficients in short seals can be extracted from purely static force measurements. A theoretical basis for this along with experimental corroboration presented. Since static measurements are much simpler than fully dynamic ones this represents a major step forward in the state-of-the-art.

b. The coupling between the seal perturbation flow and the upstream plenum flow can not be ignored in general. This coupling can augment the force level by a factor of four (4) under some circumstances. The general theory

developed for this not only explained the data of Millsaps (1) but also those of Benkert & Wachter.

(3) Analytical work on the forces generated by geometrically imperfect sealing knives and inner glad surfaces have been investigated. It has been found that very small asymmetries can create radial of the same order of magnitude as residual unbalance in high power density machines. Guidelines which can be used by engine designers, have been developed. This work will be published (6).

PUBLICATIONS: Millsaps, K.T. and Martinez, M., "Dynamic Forces from Single Gland Labyrinth Seals: Part I - Ideal and Viscous Decomposition," International Gas Turbine Conference, Paper 93-GT-302, Cincinnati, OH, 23-27 May 1993.

Millsaps, K.T. and Martinez, M., "Dynamic Forces from Single Gland Labyrinth Seals: Part II - Upstream Coupling," International Gas Turbine Conference, Paper 93-GT-322, Cincinnati, OH, 23-27 May 1993.

Millsaps, K.T. and Martinez, M., "Rotodynamic Forces in Labyrinth Seals: Theory and Experiment," Seventh Conference on Rotodynamic Instability Problems in High-Performance Turbomachinery, Texas A&M University, 10-12 May 1993.

Millsaps, K.T. and Martinez, M., "Dynamic Forces from Single Gland Labyrinth Seals: Part I - Ideal and Viscous Decomposition," ASME Journal of Turbomachinery, accepted for

publication.

Millsaps, K.T. and Martinez, M., "Dynamic Forces from Single Gland Labyrinth Seals: Part II - Upstream Coupling," ASME Journal of Turbomachinery, accepted for publication.

Millsaps, K.T. and Williston, W.C., "Synchronous Rotor Vibration Driven by a Rotating Geometrically Imperfect Labyrinth Seal," accepted for the scheduled 1994 International Gas Turbine Conference, Den. Haag, The Netherlands.

CONFERENCE PRESENTATIONS: Millsaps, K.T. and Martinez, M., "Dynamic Forces from Single Gland Labyrinth Seals: Part I - Ideal and Viscous Decomposition," International Gas Turbine Conference, Cincinnati, OH, 23-27 May 1993.

Millsaps, K.T. and Martinez, M., "Dynamic Forces from Single and Labyrinth Seals: Part II - Upstream Coupling," International Gas Turbine Conference, Cincinnati, OH, 23-27 May 1993.

Millsaps, K.T. and Martinez, M., "Rotodynamic Forces in Labyrinth

Seals: Theory and Experiment," Seventh Conference on Rotodynamic Instability Problems in High-Performance Turbomachinery, Texas A&M University, 10-12 May 1993.

THESES DIRECTED: Williston, William C., LCDR, USN, "Synchronous Vibrations resulting from Non-Uniform Labyrinth Seal Gaps," Master's Thesis.

Konicki, Joseph S., LT, USN, "Design of a 2-Dimensional Planar Labyrinth Seal Test Facility," Master's Thesis.

OTHER: Millsaps, K.T. and Williston, W.C., "Synchronous Rotor Vibration Driven by a Rotating Geometrically Imperfect Labyrinth Seal," accepted for the 1994 International Gas Turbine Conference, Den Haag., the Netherlands.

DOD KEY TECHNOLOGY AREA: Propulsion and Energy Conversion.

KEYWORDS: Labyrinth Seals, Fluid-Induced Forces, Synchronous Vibrations.

ROTODYNAMICS TEST FACILITY

K.T. Millsaps, Jr., Assistant Professor
Department of Mechanical Engineering
Sponsor and Funding: Unfunded

OBJECTIVE: To build a research facility for dynamic balancing, rotodynamic instability and magnetic bearing investigations.

SUMMARY: A rotodynamics test facility has been developed. This table top rig consists of a Bentley Nevada rotor kit along with appropriated instrumentation. A lab PC 486-66 along with a PC data acquisition board and software is being used to acquire and process the data. It has demonstrated the

ability to function and produce repeatable results. It will be used for both validating balancing techniques as well as measuring self-exciting forces on orbiting shafts. It will also be used for vibration laboratory experiment.

DOD KEY TECHNOLOGY AREA: Propulsion and Energy Conversion.

KEYWORDS: Rotodynamics, Model Balancing, Rotodynamic, Instabilities, Magnetic Bearings.

CONTROL OF UNDER-ACTUATED ROBOT MANIPULATORS

R. Mukherjee, Assistant Professor
Department of Mechanical Engineering
Sponsor and Funding: Naval Postgraduate School

OBJECTIVE: The goal of this research was to (a) investigate the kinematic and dynamic behavior of under-actuated dynamical systems, of robot manipulators in particular, in the presence of first and second order nonholonomic constraints of motion, and (b) establish motion planning and control schemes for the under-actuated system.

SUMMARY: Mechanical systems that are under-actuated will have a number of advantages over completely actuated systems. Such systems are however difficult to control. In this project we investigated the control of a free-flying under-actuated space manipulator and a three-link planar under-actuated manipulator on earth. In the case of the terrestrial manipulator we have shown that it is possible to reach any joint configuration from any other if the passive joint is provided with a rotary dashpot. We have also shown that our control is robust to variations in certain parameters and unmodelled dynamics. In the case of the space manipulator we have shown that greater control can be achieved if the passive joints are not cyclic coordinates.

PUBLICATIONS: Mukherjee, R. and

Chen, D., "Control of Free-Flying Under-Actuated Space Manipulators to Equilibrium Manifolds," IEEE Transactions on Robotics and Automation, Vol. 9, No. 5, October 1993.

Mukherjee, R. and Jordan, P., "Feedback Control of a Three Link Planar Under-Actuated Manipulator Using a "Surge" Velocity," ASME Winter Annual Meeting, New Orleans, LA, 1993.

CONFERENCE PRESENTATION: Mukherjee, R. and Jordan, P., "Feedback Control of a Three Link Planar Under-Actuated Manipulator Using a "Surge" Velocity," ASME Winter Annual Meeting, New Orleans, LA, 1993.

THESIS DIRECTED: Jordan, P., "Feedback Control of a Three Link Planar Under-Actuated Manipulator Using a "Surge" Velocity," Master's Thesis, September 1993.

DOD KEY TECHNOLOGY AREA: Design Automation.

KEYWORDS: Under Actuated, Space Manipulators and Surge Velocity.

**NONHOLONOMIC MOTION PLANNING AND
SPACE MANIPULATOR CONTROL**

**R. Mukherjee, Assistant Professor
Department of Mechanical Engineering
Sponsor and Funding: Unfunded**

OBJECTIVE: The goal of this project was to develop a motion planning scheme for nonholonomic systems and apply it to a space multibody system for attitude control.

SUMMARY: As a part of this project we developed the surface integral algorithm for nonholonomic motion planning. This algorithm was used to plan trajectories for several nonholonomic systems. The algorithm was particularly useful for the attitude control of a space structure using a three link rigid robot manipulator.

PUBLICATIONS: Nakamura, Y. and Mukherjee, R., "Exploiting Nonholonomic Redundance in Free-Flying Space Robots," IEEE Transactions on Robotics and Automation, Vol. 9, No. 4, pp. 499-506, August 1993.

Mukherjee, R. and Junkins, J.L., "Invariant Set Analysis of the Hub-Appendage Problem," AIAA Journal of Guidance, Control, and Dynamics, Vol. 16, No. 6, pp. 1191-1193, November 1993.

Mukherjee, R. and Anderson, D.P., "Nonholonomic Motion Planning Using Stokes' Theorem," IEEE International Conference on Robotics and Automation, Atlanta, GA, 1993.

Mukherjee, R., "A Surface Integral Approach to the Motion Planning of Nonholonomic Systems," American Control Conference, San Francisco, CA, 1993.

Mukherjee, R. and Zurowski, M., "Attitude Control of a Space

Structure Using a 3-R Rigid Manipulator," AIAA Guidance, Navigation and Control Conference, Monterey, CA, 1993.

CONFERENCE PRESENTATIONS: Mukherjee, R. and Anderson, D.P., "Nonholonomic Motion Planning Using Stokes' Theorem," IEEE International Conference on Robotics and Automation, Atlanta, GA, 1993.

Mukherjee, R., "A Surface Integral Approach to the Motion Planning of Nonholonomic Systems," American Control Conference, San Francisco, CA, 1993.

Mukherjee, R., "An Invariant Set Analysis of the Hub-Appendage Problem," American Control Conference, San Francisco, CA, 1993.

Mukherjee, R. and Zurowski, M., "Attitude Control of a Space Structure Using a 3-R Rigid Manipulator," AIAA Guidance, Navigation and Control Conference, Monterey, CA, 1993.

THESES DIRECTED: Zurowski, M., LT, USN, "Trajectory Planning for Space Manipulators," Master's Thesis, December 1993.

Maddox, Douglas, LT, USN, "An Experimental Testbed for a Free Floating Manipulator," Master's Thesis, December 1993.

DOD KEY TECHNOLOGY AREA: Design Automation.

KEYWORDS: Space Robots, Nonholonomic Motion Planning, Attitude Control, and Surface Integral.

NONLINEAR VEHICLE GUIDANCE AND CONTROL DYNAMICS

F.A. Papoulias, Assistant Professor

Department of Mechanical Engineering

Sponsor and Funding: ONR and Naval Postgraduate School

OBJECTIVE: The goal of this project was to study the nonlinear dynamics originating from interactions of guidance and control functions of marine vehicles.

SUMMARY: Separation of guidance and control functions of an autonomous vehicle is necessary for proper negotiation of the vehicle and its environment. For accurate path keeping the dynamics of the guidance law must be as fast as possible. This sets a lower bound for the autopilot reaction time. Ocean vehicles suffer from a number of dynamic lags in their motion response and actuator sizing, and these lags set an upper bound for their reaction time. At the intersection of these two bounds, it is possible that loss of stability of the entire guidance/autopilot scheme may occur. The results of this project indicated that the mechanism of stability loss is through bifurcations to periodic solutions although solution branching has also been observed in certain cases. In order to analyze stability properties of the resulting periodic solutions we proceed with a systematic nonlinear study, utilizing bifurcation theory, center manifold reduction, and integral averaging. The results demonstrated the existence of either subtle or catastrophic bifurcations to periodic solutions and provided estimates of their amplitude and period. It was shown that application of nonlinear dynamics techniques is necessary for reliable estimates of vehicle operational envelopes for given environmental conditions and mission specifications.

PUBLICATIONS: Papoulias, F.A., "Loss of Stability of Guidance and Control Laws for Autonomous Vehicles," Dynamics and Stability of Systems, Vol. 8, No. 2, pp. 101-125, March 1993.

Papoulias, F.A., "Dynamics and Bifurcations of Pursuit Guidance for Vehicle Path Keeping in the Dive Plane," Journal of Ship Research, Vol. 37, No. 2, pp. 148-165, June 1993.

Papoulias, F.A., "On the Nonlinear Dynamics of Pursuit Guidance for Marine Vehicles," Journal of Ship Research, Vol. 37, No. 4, pp. 342-353, December 1993.

CONFERENCE PRESENTATIONS: Papoulias, F.A., "Nonlinear Vehicle Guidance and Control Dynamics," University of Michigan/Sea Grant/MIT Workshop on Offshore Station Keeping, Ann Arbor, MI, May 1993.

Papoulias, F.A., "The N.P.S. AUV Project," ONR Workshop on Nonlinear Adaptive Control, College Park, MD, September 1993.

THESES DIRECTED: Oral, Z.O., LT, Turkish Navy, "Hopf Bifurcations in PathControl of Marine Vehicles," Master's Thesis, June 1993.

Cummings, G.P., LCDR, U.S. Coast Guard, "Enhancing Path Stability Characteristics of Marine Vehicles in the Presence of Positional Information Time Lags," Master's Thesis, September 1993.

DOD KEY TECHNOLOGY AREA: Design
Automation.

KEYWORDS: Nonlinear Dynamics,
Guidance, Control.

NUMERICAL ANALYSIS OF UNSTEADY FLOW ABOUT BLUFF BODIES

T. Sarpkaya, Distinguished Professor

Department of Mechanical Engineering

Sponsor and Funding: National Science Foundation

OBJECTIVE: Continuing computational and experimental fluid dynamics research towards the understanding of the effect of unsteadiness on the characteristics of the resulting time-dependent flow and resistance.

SUMMARY: A two-step, three-level, finite-difference, predictor-corrector scheme (based on the second-order Adams-Bashforth method) and a Fast Poisson Solver based on FFT methods are used to carry out the numerical experiments. A von Neumann linear stability analysis was performed and the mesh sizes and time steps were chosen to provide a conditionally stable solution. The physical experiments were carried out in a U-shaped oscillating-flow tunnel for various Reynolds and Keulegan-Carpenter numbers. The results were found to be in reasonable agreement with those obtained experimentally. The methodology has been extended to Gaussian oscillations of the flow about a cylinder to simulate the ocean environment.

PUBLICATIONS: Sarpkaya, T., "Offshore Hydrodynamics," Journal of Offshore Mechanics and Arctic Engineering, Trans. ASME, Vol. 115, No. 1, pp. 2-5, February 1993.

Sarpkaya, T., Putzig, C., Gordon, D., Wang, X., and Dalton, C., "Vortex Trajectories Around a Circular Cylinder in Oscillatory Plus Mean Flow," Journal of Offshore Mechanics and Arctic Engineering, Trans. ASME, Vol. 114, No. 4, pp. 291-298, November 1992.

THESIS DIRECTED: Vanover, K.C., LT, USN, "Numerical Analysis of Transitory Oscillating Flow About a Cylinder," Master's Thesis, June 1993.

OTHER: Sarpkaya, T., "Vortex Element Methods for Flow Simulation," in Advances in Applied Mechanics, Th. Wu and H. Hutchinson, eds., Academic Press, in press, due to appear April 1994.

Sarpkaya, T., "Unsteady Flows: Analysis and Experiments," in Handbook of Fluid Dynamics, J.A. Schetz, (Senior Editor), John Wiley & Sons, in press, due to appear June 1994.

DOD KEY TECHNOLOGY AREA: Other.

KEYWORDS: Computational Fluid Dynamics, Vortex Motion, Bluff Bodies.

TURBULENT VORTEX/FREE-SURFACE INTERACTIONS

T. Sarpkaya, Distinguished Professor

Department of Mechanical Engineering

Sponsor and Funding: Chief of Naval Research (ONR)

OBJECTIVE: The continuation of basic and applied research towards the understanding of the phenomena resulting from the interaction of turbulent vortices with clean or contaminated free surface. The quantification of the characteristics of turbulence (stresses, structures and turbulent kinetic energy) through extensive measurements (LDV), flow visualization (LIF), Proper-Orthogonal-Decomposition (POD) and numerical analysis.

SUMMARY: The statistical as well as structural characteristics of the turbulent flow field resulting from the interaction of single or dipole turbulent vortices with clean and contaminated free surfaces were investigated in order to elucidate the physics of the phenomena relevant to the understanding of near-surface structures in ship-generated wakes.

Turbulence intensities, energy spectra, and turbulent stresses are measured with an LDV in the region between a single trailing vortex and the free surface. Amplification of the streamwise and transverse components of turbulent velocity, coupled with a sharp reduction in the vertical turbulent velocity, was found near the free surface. The energy spectra shows that, as the free surface is approached, there is a preferential attenuation of low frequencies (large scales) for the vertical velocity fluctuations and a net energy gain at the same frequencies for the streamwise and transverse turbulence components. Thus, the free-surface redistributes the normal component of the turbulent kinetic energy into streamwise and

spanwise components at large eddy scales, and renders the near-free-surface turbulence strongly anisotropic. The predominant coherent structures are (i) swirling surface depressions whose preferential merging leads to reverse energy cascade and eddy longevity, and (ii) flattened large eddies with axes nearly parallel to the free surface. The entire process is driven by the underlying, nearly isotropic, three-dimensional turbulence field.

PUBLICATIONS: Sarpkaya, T., "Coherent Structures in Oscillatory Boundary Layers," Journal of Fluid Mechanics, Vol. 253, pp. 105-140, August 1993.

Sarpkaya, T. and Carroll, J.B., "Interaction of a Turbulent Vortex with a Free Surface," in Proceedings of the Nineteenth Symposium on Naval Hydrodynamics, National Academy Press, Vol. 1, pp. 163-174, September 1993.

Sarpkaya, T., "Review of the Mechanics of Fluids," Applied Mechanics Reviews, Vol. 45, No. 10, pp. 143, October 1993.

Sarpkaya, T., "Review of the Benard Cells and Taylor Vortices," Applied Mechanics Review, Vol. 46, No. 9, pp. 127-128, September 1993.

Sarpkaya, T. and Neubert, D., "Interaction of a Streamwise Vortex with a Free Surface," American Institute of Aeronautics and Astronautics Journal, accepted for publication, due to appear March 1994.

CONFERENCE PRESENTATIONS: Sarpkaya, T. and Neubert, D., "Interaction of a Streamwise Vortex with a Free Surface," AIAA-93-0556, 31st Aerospace Sciences Meeting, Reno, NV, 11-14 January 1993.

Sarpkaya, T., "Vorticity/Free-Surface Interaction," in Proceedings of the International Conference on Vorticity/Boundary Interactions, Vol. 1, pp. 1-17, 25-30 September 1993.

Sarpkaya, T., "On the Instability of the Stokes Boundary Layer," in Near-Wall Turbulent Flows, R.M.C. So, C.G. Speziale and B.E. Launder, (Eds), Elsevier Science Publishers, Vol. 1, pp. 479-488, 8-12 March 1993.

THESES DIRECTED: Carroll, J.B., "Free-Surface/Vorticity Interaction," Master's Thesis, September 1993.

Merrill, C.F., LT, USN, "Numerical Analysis of Single-Vortex/Free-Surface Interaction," Master's Thesis, December 1993.

Magee, M.P., LT, USN, "Spectral Characteristics of the Vortex/Free-Surface Interaction," Master's Thesis, December 1993.

Neubert, Jr., D.C., LT, USN, "Trailing Vortex/Free-Surface Interaction," Master's Thesis, December 1992.

DOD KEY TECHNOLOGY AREA: Other.

KEYWORDS: Vorticity, Free Surface, Surface Signatures, SAR Images.

**DYNAMIC RESPONSE AND FAILURE OF COMPOSITE AND METAL
STRUCTURES TO UNDERWATER EXPLOSIONS**

Y.S. Shin, Professor

Y.W. Kwon, Associate Professor

Department of Mechanical Engineering

Sponsor and Funding: Defense Nuclear Agency

OBJECTIVE: To advance our understanding on the shock induced dynamic response and failure mechanism of composite and metal structures to underwater explosions.

SUMMARY: The significant progress in this research has been made in understanding the nonlinear dynamic response, the failure process and physics of submarine hull collapse when subjected to underwater explosions (UNDEX). This project is a continuation of the effort performed in FY92 in which DYNA3D (Nonlinear Dynamic Analysis of Structures in Three Dimensions) code was coupled with USA (Underwater Shock Analysis) code and USA-DYNA3D code has been fully operational at Naval Postgraduate School. The research efforts were divided into two areas in FY93; (i) the damage response of submerged imperfect cylindrical structures to UNDEX, and (ii) the dynamic response of multi-ply composite circular cylinder to UNDEX. The effect of the initial geometric imperfections to the damage response of submerged structures to UNDEX was investigated. The type of the submerged structure investigated was the ring-stiffened long circular cylinders submerged in the fluid. The strain hardening mild steel was used in the analysis. The modal imperfection concept was used to stimulate the initial geometric imperfections. The numerical analyses were performed to looking into the details of damage response of ring-stiffened cylindrical shells. The following models were considered: (i) 2D infinite circular cylinder

models, and (ii) 3D infinite and finite length ring-stiffened cylinders models. The computational results showed that the dynamic buckling or dishing type of shell deformation was very much pronounced in the imperfect models, which compared well with the UNDEX test results. For the dynamic response of multi-ply composite circular cylinder, finite element model was developed for 10 plies of S2-glass/epoxy ([0/45/90/-45/90/45/90/-45/90/90] composite cylinder subjected to side-on attack geometry. The numerical results of the elastic strain response compares well with the experimental measurements in early times. However, the results diverge at late times. Both material damage as well as geometric imperfections in the composite cylinder were studied to investigate this discrepancy.

PUBLICATIONS: Hooker, D.T., Shin, Y.S., and Kwon, Y.W., "Effect of Initial Imperfections on the Response of Cylinders to Underwater Shock," in Proceedings of the 64th Shock and Vibration Symposium, Vol. II, Fort Walton Beach, FL, 26-28 October 1993.

Rousseau, M.P., Kwon, Y.W., and Shin, Y.S., "Dynamic Response of a Filament Wound Composite Cylinder Exposed to Underwater Shock," in Proceedings of the 64th Shock and Vibration Symposium, Vol. III, Fort Walton Beach, FL, 26-28 October 1993.

Hooker, D.T., Shin, Y.S., and Kwon, Y.W., "Effect of Initial Imperfections on the Response of

Cylinders to Underwater Shock," NPS Technical Report NPS-ME-93-006, December 1993.

Rousseau, M.P., Kwon, Y.W., and Shin, Y.S., "Dynamic Response of a Filament Wound Composite Cylinder Exposed to Underwater Shock," NPS Technical Report NPS-ME-93-005, December 1993.

CONFERENCE PRESENTATIONS: Hooker, D.T., Shin, Y.S., and Kwon, Y.W., "Effect of Initial Imperfections on the Response of Cylinders to Underwater Shock," 64th Shock and Vibration Symposium, Fort Walton Beach, FL, 26-28 October 1993.

Rousseau, M.P., Kwon, Y.W. and Shin, Y.S., "Dynamic Response of a Filament Wound Composite Cylinder Exposed to Underwater Shock," 64th Shock and Vibration Symposium, Fort Walton Beach, FL, 26-28 October 1993.

THESES DIRECTED: Hooker, D.T., LT, USN, "Effect of Initial Imperfections on the Response of Cylinders to Underwater Explosion," Engineer's Degree in Mechanical Engineering, December 1993.

Rousseau, M.P., LT, USN, "Dynamic Response of a Filament Wound Composite Cylinder Exposed to Underwater Shock," Master's Thesis, September 1993.

OTHER: Y.S. Shin gave the invited 3 hour lectures on Underwater Explosions and Their Responses to Structures at the 64th Shock and Vibration Symposium, Fort Walton Beach, FL, 26-28 October 1993.

DOD KEY TECHNOLOGY AREA: Other.

KEYWORDS: Underwater Explosion, Composites, Initial Imperfection Effects, Nonlinear Dynamic Response.

**DYNAMIC RESPONSE OF COMBAT SYSTEM EQUIPMENT
TO UNDERWATER EXPLOSION**

Y.S. Shin, Professor

Department of Mechanical Engineering

Sponsor and Funding: Naval Sea Systems Command, Code 03K213

OBJECTIVE: To develop, design, build and testing "tuned" mounting fixture to simulate the ship-shock environment and its effect to combat system equipment using U.S. Navy's Mediumweight Shock Machine with tuned mounting fixture.

SUMMARY: Shipboard combat system equipment must be designed to withstand severe shock excitations induced by underwater explosion, either conventional or nuclear. The response of combat system equipment to underwater explosion is basically vibrational in nature. The equipment tends to vibrate at its fundamental natural frequency or a low range of natural frequencies, when excited by the shock wave. The maximum amplitude of the vibration usually occurs after the shock wave passes the ship. The shock response wave form is remarkably different at various levels within the ship. In essence, the ship acts as a low pass mechanical filter which alters the characteristics of the propagating shock wave from one possessing high frequency components to one that contains relatively low frequency components. Thus, the shock qualification for combat system equipment, which are usually located in upper levels of the ship, is a vibration problem in which relatively low frequency equipment support foundation excitations are observed. The U.S. Navy's shock qualification requirements are mandated in MIL-S-901D. Of particular interest is the U.S. Navy's Mediumweight Shock Machine (MWSM) used for shock qualification of equipment ranging

from 230 to 6000 lbs. This hammer anvil device delivers high energy, high frequency shock excitation to items affixed to it. This type of high frequency excitation waveform is significantly different from the actual waveforms that have been observed at various equipment locations during ship shock trials. The differences can be reduced by substituting a specially designed "tuned" test mounting fixture for the default mounting fixtures currently used to affix test items to the MWSM. A tuned mounting fixture, designed to respond at specific natural frequencies when excited by the MWSM, will provide a better simulation of the actual shock phenomena experiences by shipboard equipment. The multi-DOF tuned mounting fixture was designed by NPS and fabricated by CDNSWC. The initial shock testing using U.S. Navy's mediumweight shock machine with designed tuned mounting fixture was performed at NUSC, Newport, RI, and the analytical results were compared with those of tests.

PUBLICATION: Cox, D.M., Shin, Y.S., and McLean, M., "Design of a Multi-DOF Tuned Mounting Fixture for the Navy's Mediumweight Shock Machine," in Proceedings of the 64th Shock and Vibration Symposium, Vol. II, Fort Walton Beach, FL, 26-28 October 1993.

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THESIS DIRECTED: Cox, D.M., LT, USN,
"Design of a Multi-DOF Tuned Mounting
Fixture for the Navy's Mediumweight
Shock Machine," Master's Thesis,
June 1993.

DOD KEY TECHNOLOGY AREA: Other.

KEYWORDS: Mediumweight Shock
Machine, Multi-DOF Tuned Mounting
Fixture, Underwater Explosion, Shock
Spectra.

**SHIPBOARD MACHINERY CONDITION MONITORING AND
DIAGNOSTICS: ANALYSIS, APPROACH AND ASSESSMENT OF
VIBRATION CRITERIA**

Y.S. Shin, Professor

Department of Mechanical Engineering

**Sponsor and Funding: Naval Ship Systems Engineering
Station (NAVSSSES)**

OBJECTIVE: The scientific objectives include to review the current Assessment of Equipment Condition (AEC) methodology for vibration criteria, perform statistical analysis of vibration data taken from shipboard machinery such as fire pump, and establish the alert criteria as a means of assessing machinery condition.

SUMMARY: This is a new research project for basic and applied research in shipboard machinery condition monitoring and diagnostics. The vibration alert level plays a vital role in a machinery condition monitoring and diagnostics for early warning of fault development in the machinery. Two approaches in setting the vibration alert level were studied in time and frequency domains using the vibration signals generated by shipboard fire pumps. In time domain approach, cross peak analysis (CPA) was developed to extract the dominant peak envelop amplitude between the zero crossings. The statistical analysis of the measured data showed that the peak envelop distribution follows the log normal distribution in a linear velocity

scale. However, it follows the Gaussian distribution in a velocity dB(VdB) scale. With the Gaussian distribution, the mean plus two standard deviations in VdB was determined as a broadband alert level with 97.7% of acceptance level. In the frequency domain approach, 1/1 full Octave Band Analysis (OBA) was performed, which divides the frequency spectrum into constant percentage bands. The results of the studies show that the change in VdB level in frequency is more pronounced in OBA than that of the broadband level.

PUBLICATION: Liu, C.S., Jeon, J.J., and Shin, Y.S., "Analysis, Approach and Assessment of Vibration Criteria in Shipboard Machinery Condition Monitoring and Diagnostics," NPS Technical Report NPS-ME-93-005A, 30 September 1993.

THESIS DIRECTED: Liu, C.S., CAPT, Republic of China, "Analysis, Approach and Assessment of Vibration Criteria in Shipboard Machinery Condition Monitoring and Diagnostics," Master's Thesis, December 1993.

OTHER: Shin, Y.S. and Liu, C.S.,
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Machinery Condition Monitoring and
Diagnostics," submitted for
publication in Journal of Naval
Engineers.

DOD KEY TECHNOLOGY AREA: Other.

KEYWORDS: Shipboard Machinery,
Monitoring, Vibration Alert Level,
Shipboard Fire Pump, Condition
Monitoring and Diagnostics.

SHOCK AND VIBRATION RESEARCH IN SUPPORT OF ALISS
(Advanced Lightweight Influence Sweep System)

Y.S. Shin, Professor

Department of Mechanical Engineering

**Sponsor and Funding: Cardrock Division of Naval Surface
Warfare Center**

OBJECTIVE: The scientific objectives include: (i) to study the operational environment in which the ALISS must be designed to perform and to make a recommendation on shock and vibration design criteria, (ii) to conduct a review of the magnet shock test apparatus currently in use and to make any design modification if any, and (iii) to review the common cryogenic supports which are candidates for use in the ALISS and to design a shock test apparatus to test the performance of these cryogenic supports.

SUMMARY: This is a new shock and vibration research project in support of Advanced Lightweight Influence Sweep System (ALISS). ALISS is an Advanced Technology Demonstration to validate the feasibility of superconducting technology to sweep magnetic influence mines. Mine countermeasures (MCM) are conducted to clear or map a safe passage through anti-invasion mine fields. The Navy has already identified

critical deficiencies in their capability to conduct rapid MCM in support of a "surface forcible entry." Characteristics of MCM systems currently used to counter magnetic influence mines restrict sweep rates, limit sweep rates, limit the ability to accurately simulate a ship's magnetic signature, and require a minimum water depth. Advances in superconducting technology over the last twenty years have significantly increased the feasibility of superconducting mine countermeasures (SCMCM) for magnetic influence mines. A SCMCM system should be small, light, and simple compared to currently deployed MCM system. When ALISS (Advanced Lightweight Influence Sweep System) is constructed as a superconducting mine countermeasure, the system must perform satisfactorily under the extremes of shock and vibration environment encountered in military applications. An instantaneous relative motion between the superconducting coil and its support

or between a segment of the superconducting coil and another can cause sufficient frictional heating to raise the temperature of the coil locally above the critical temperature of the superconductor. When raised above its critical temperature, the superconducting material suddenly changes from its superconducting state into a normal, resistive state. The very high electrical currents carried by the superconductor must suddenly be carried by a normally resistive wire, with the result that the resistive heating rapidly raises the temperature further. The high magnetic field of the superconducting coil collapses. To restore its usefulness, all power must be removed from the coil, and the coil must again be cooled to the very low

cryogenic temperatures below the critical temperature at which the material is superconductive. Power may then be applied to restore the magnetic field of the superconducting coils and return the motor or generator to useful service. The tasks conducted include the definition of the shock and vibration environment, design modification of the magnet shock test apparatus and design of a cryogenic support shock test apparatus.

THESIS DIRECTED: Hoy, Eric, LT, USN, has been working on this project.

DOD KEY TECHNOLOGY AREA: Other.

KEYWORDS: ALISS, Superconducting Mine Countermeasures, Light Weight Influence Mine Sweep System, Shock and Vibration.

**DEPARTMENT
OF
MECHANICAL ENGINEERING**

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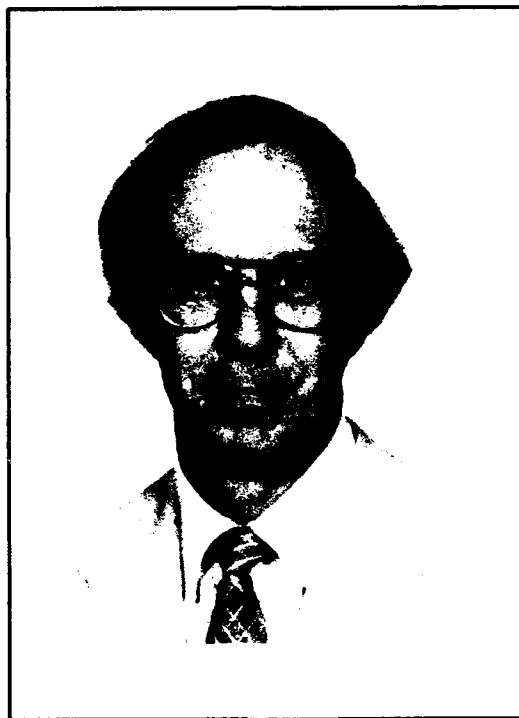
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**DEPARTMENT
OF
METEOROLOGY**



**Robert L. Haney
Chairman**

DEPARTMENT OF METEOROLOGY

The Department of Meteorology has a very active research program in areas of Navy relevance. In 1993 we saw a number of important upgrades in our research facilities that support these research programs. These upgrades in facilities are given below, followed by a list of the research areas and major research programs in the department and a list of the faculty points of contact for these areas and specific programs. Details of the various research efforts are found in the research project summaries that follow.

UPGRADED RESEARCH FACILITIES

IDEA LAB - 16 SGI workstations
- NEXRAD PUP ('95)

CRAY Mini-Supercomputer on Campus

MEASUREMENTS LAB - 405 MHz Boundary Layer Wind Profiler
- 915 MHz Boundary Layer Wind Profiler
- ASOS Installation ('95)

TACTICAL LAB - SMQ-11 Installation

SYNOPTIC LAB - Interactive Projection & Display System

RESEARCH AREAS AND MAJOR RESEARCH PROGRAMS

TROPICAL/TROPICAL CYCLONES (9 Faculty)

TCM-90, -92, -93 (ONR)
GLOBAL/MONSOONS (NSF, NRL)

COASTAL MEASUREMENTS AND MODELING (7 Faculty)

COASTAL ARI (ONR)
REAL-TIME COASTAL ANALYSIS (ONR)
EASTERN BOUNDARY CURRENTS ARI (ONR)
RPAs (ONR)

SYNOPTIC/FORECASTING (9 Faculty)

COMET (NWS/NSF)
PICKET FENCE (NSF)

NUMERICAL ANALYSIS/PREDICTION (7 Faculty)

FRONTAL MODELING (NSF)

BOUNDARY LAYER/AEROSOLS (3 Faculty)

LEADEX (ONR)
ASTEX (ONR)

ATMOSPHERIC ERSO (2 Faculty)
VOCAR (NRaD)
MAPTIP (NRaD)

REMOTE SENSING (3 Faculty)
SHIP TRACKS (OMR)
RPAs (OMR)
NORCSEX/ERS-1 (NRL)

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RESEARCH POINTS OF CONTACT

TROPICAL/TROPICAL CYCLONES (9 Faculty)

L. E. Carr (x2374) - TCM
R. L. Elsberry (x2373) - TCM-90, -92, -93
C.-P. Chang (x2840) - GLOBAL/MONSOONS
R. T. Williams (x2296) - TCM, GLOBAL/MONSOONS

COASTAL MEASUREMENTS AND MODELING (7 Faculty)

K. L. Davidson (x2309) - VOCAR
P. A. Durkee (x3465) - RPAs
R. L. Haney (x2517) - EASTERN BOUNDARY CURRENTS ARI
T. R. Holt (x2861) - COASTAL ARI
W. A. Nuss (x2308) - COASTAL ARI, REAL-TIME COASTAL ANALYSIS
C. H. Wash (x2295) - VOCAR

SYNOPTIC/FORECASTING (9 Faculty)

C.-P. Chang (x2840) - COMET
W. A. Nuss (x2308) - COMET
C. H. Wash (x2295) - COMET
R. L. Elsberry (2373) - STORM FIST (PICKET FENCE)

NUMERICAL ANALYSIS/PREDICTION (7 Faculty)

W. A. Nuss (x 2308) - REAL-TIME COASTAL ANALYSIS
R. T. Williams (x2296) - FRONTAL MODELING

BOUNDARY LAYER/AEROSOLS (3 Faculty)

P. A. Durkee (x3465) - RPAs, ASTEX
K. L. Davidson (x2309) - LEADEX
T. R. Holt (x2861) - COASTAL ARI

ATMOSPHERIC EMEO (2 Faculty)

K. L. Davidson (x2309) - VOCAR, MAFITP

C. H. Wash (x2295) - VOCAR, MAFITP

REMOTE SENSING (3 Faculty)

K. L. Davidson (x2309) - ERS-1/MORCSEK

P. A. Durkee (x3465) - SHIP TRACKS, ASTEX

C. H. Wash (x2295) - VOCAR

TROPICAL AND MONSOON STUDIES

C.-P. Chang, Professor

R.T. Williams, Professor

Department of Meteorology

Sponsor and Funding: National Science Foundation

OBJECTIVE: The purpose of this project is to study the structure and behavior, including the dynamical and thermodynamic mechanisms, of large- and cyclone-scale atmospheric motion systems in the tropics and subtropics, particularly those in the western Pacific and the Asian monsoon region.

SUMMARY: An empirical reliability study was completed to test the sensitivities of the Multiple-set Canonical Correlation Analysis (MCCA) developed last year. The technique generalizes the conventional two-set Canonical Correlation Analysis. The case study used an MCCA application of the 850 hPa meridional wind data over the tropical western Pacific to study tropical synoptic wave disturbances during summer. The successive 12-hour meridional winds were used as different data fields. The result shows that the method is stable with respect to sampling changes when the data contain significant signals of physical phenomenon, and not stable when the data are random. The study also confirmed the use of the largest residual correlation (LRC), or the largest cross-component correlation, as a preliminary significance test for the technique.

To understand the East Asian summer monsoon Mei-yu system, the three dimensional flow of a stratified barotropic flow over isolated topography was first studied. When the Froude number was small it was found that the Coriolis force could not be ignored for flow over small scale mountains. For larger scale

mountains a lee side through was found which could be either stationary or transient. Under certain conditions a train of troughs were generated. The influence of topography on fronts was studied in a channel which contained an unstable baroclinic flow. First a cyclone was allowed to grow and intense cold and warm fronts were formed. Then the frontal system was introduced into a new domain which contained a mountain. The influence of the mountain on the cold front was determined for five mountains which had various sizes, shapes and orientations.

PUBLICATIONS: Chang, C.-P., Yeh, T.C., and Chen, J.M., "Effects of Terrain on the Surface Structure of Typhoons over Taiwan," Monthly Weather Review, Vol. 121, No., pp. 734-752, March 1993.

Chang, C.-P. and Zambresky, L., "Observed and Navy Operational Global Model Climatologies of Synoptic Disturbances over the Tropical Western Pacific during Winter 1991-92," NPS Technical Report MR-93-003, 1993.

Chen, J.M. and Chang, C.-P., "Multiple-set Canonical Correlation Analysis of Winter Monsoon Cold Surges over the South China Sea," East Asia and Western Pacific Meteorology and Climate II, World Scientific, pp. 337-342, 1993.

Peng, M.S., Li, S.W., Chang S.W., and Williams, R.T., "Flows over Mountains: Coriolis Force, Transient Trough and Three Dimensionality,"

East Asia and Western Pacific Meteorology and Climate II, World Scientific, pp. 73-82, 1993.

CONFERENCE PRESENTATIONS: Chang, C.-P., "A Proposed Field Experiment to Study the East Asian Summer Monsoon Onset over the South China Sea," International Conference on Weather Analysis and Forecasting over the Western Pacific, Pacific Science Association, Taipei, Taiwan, February 1993.

Chang, C.-P., Chen, J.M., Harr, P.A., and Carr, L.E., "Synoptic-Scale Propagating Wave Patterns and Typhoon Periodicity in the Tropical Western Pacific during summer 1989-1991," 5th U.S. - P.R.C. Monsoon Workshop, Hanzhou, China, June 1993.

Li, S.-W., Peng, M.S., and Williams, R.T., "Three-dimensional Studies of the Effects of Topography on the Fronts," Sixth Conference on Mountain Meteorology, Portland, OR, 29 September-2 October 1992.

THESES DIRECTED: Yeh, T.C. "Effects of Taiwan Orography on the Motion and Structure of Taiwan," Ph.D. Dissertation, December 1992.

Li, S.W., "A Three-Dimensional Study of the Influence of Mountains on a Front," Ph.D. Dissertation, December 1992.

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OTHER: Chen, J.M., Chang, C.-P., and Harr, P.A., "A Technique for Analyzing Optimal Relationships among Multiple Sets of Data Fields. Part I: The Method," Monthly Weather Review, accepted for publication, December 1993.

Peng, M.S., Li, S.W., Chang, S.W., and Williams, R.T., "Flow Over Mountains: Coriolis Force, Transient Troughs and Three Dimensionality" submitted to Quarterly Journal Royal Meteorological Society, 1993.

DOD KEY TECHNOLOGY AREA: Environmental Effects.

KEYWORDS: Tropical Meteorology Monsoon, Topographic Effects, Typhoon.

FORMULATION AND VERIFICATION OF A MARINE AEROSOL MODELS

K.L. Davidson, Professor

Department of Meteorology

Sponsor: Naval Command Control and Ocean Surveillance Center,

RDT&E Division (NRaD), Code 54

Funding: Cost Share, NRaD and NPS

OBJECTIVE: Objectives of continuing data observational and analyses/interpretation efforts are to 1) evaluate existing computer based models (NAM and NOVAM) for aerosol extinction profiles, 2) formulate approaches for obtaining extinction from operational satellite-borne sensor data; i.e. NOAA AVHRR, and 3) characterize turbulent transport influences on near-surface aerosol distributions and profiles.

SUMMARY: Performed several collaborative measurements and analyses tasks designed to relate aerosol profiles within the marine boundary layer to routinely measured or predicted meteorological parameters. The atmospheric region extends from the surface up to the capping inversion. NOVAM evaluations were performed on the basis of existing data from Fire-87 and the July-August 1992 AGA/FLIR experiments. Accomplished the review of Keys-90 report for final publication. Surface layer aerosol data were collected off the US west

coast during October 1992 and August 1993 in conjunction with regional measurements of marine boundary layer refractive properties. Prepared and tested flux-buoy for use in MAPTIP experiment for which coordination was completed with regard to moorings and data transmission.

PUBLICATION: Gathman, S.G. Jensen, D.R., Hooper, W.P., James, J.E., Gerber, H.E., Davidson, K.L., Smith, M.H., Consterdine, I.E., de Leeuw, G., Kunz, G.J., and Moerman, M.M., "NOVAM Evaluation Utilizing Electro Optics and Meteorological Data from KEY-90," NRaD Technical Report TR-1608, 1993.

OTHER: Gathman, S.G. and Davidson, K.L., "The Navy Oceanic Vertical Aerosol Model," NRaD Technical Report, in press.

DOD KEY TECHNOLOGY AREA: Environmental Effects.

KEYWORDS: Aerosol, Optical Extinction, Boundary Layer.

ANALYSIS OF REGIONAL LEAD FORCING

K.L. Davidson, Professor

P.S. Guest, Meteorologist, Co-PI

P. Frederickson, Meteorologist

Department of Meteorology

Sponsor: Naval Research Laboratory, Monterey

Funding: Cost Share: Naval Research Laboratory, Monterey

OBJECTIVE: The general objectives of this study were (1) to understand the forcing mechanisms responsible for regional lead characteristics, and (2) to understand the effects of leads on regional meteorology in the Arctic.

SUMMARY: Several research papers related to this research program were submitted for publication during FY 1993. The results for these papers were based on data obtained during the Arctic Leads Experiment (LEADEx) in 1991-1992, other Arctic field programs, and modeling efforts. The results show the importance of diurnal solar radiation variations not only on surface temperature, but on momentum transfer (and hence lead formation) as well. Changes in cloud cover had a greater effect on surface temperature than typical variations in lead coverage. A study of the relation between ice motion and wind forcing showed that strong shear events, which are associated with lead formation, can be caused by non-local forcing. For example, in one case, a small cyclone passed near but not over our measurement array. The internal ice stress generated by this storm was transmitted internally within the ice for at least 200 km, causing lead formation despite light and generally spatially homogeneous winds within the actual measurement array.

PUBLICATIONS: Davidson, K.L., Guest, P.S. and Glendening, J.W., "Determining Realistic Wind Stress Forcing Fields for Marine Arctic Regions," in Proceedings of the Third Conference on Polar Meteorology and Oceanography, Portland, OR, 29 September - 2 October 1992.

Frederickson, P.A., Davidson, K.L., and Guest, P.S., "The Stratification of the Atmospheric Boundary Layer in the Arctic Marginal Ice Zone," Preprints of the Third Conference on Polar Meteorology and Oceanography, Portland, Oregon, 29 September - 2 October 1992.

Guest, P.S. and Davidson, K.L., "The Temperature and Energy Balance at the Marine Ice-Atmosphere Interface during the Polar Winter," in Proceedings of the IAMAP-IAHS conference in Yokohama Japan, July 1993.

Guest, P.S. and Davidson, K.L., "Factors Affecting Variations of Snow Surface Temperature and Air Temperature Over Sea Ice," in Proceedings of the Nansen Centennial Symposium on the Role of the Polar Oceans in Shaping the Global Environment, Solstrand-Bergen, Norway, 21-25 June 1993.

Guest, P.S., and Davidson, K.L., "A Study of the Factors controlling the Value of the Near-Surface Air Temperature over Sea Ice," Preprints

of the Third Conference on Polar Meteorology and Oceanography, Portland, OR, 29 September - 2 October 1992. (available from the American Meteorological Society, Boston MA, p. 54.

Overland, J.E., Walters, B.A., and Davidson, K.L., "Sea Ice Deformation in the Beaufort Sea," in Proceedings of the Third Conference on Polar Meteorology and Oceanography, Portland, OR, 29 September - 2 October 1992.

Persson, P.O.G., Ruffieux, D., and Davidson, K.L., "Characteristics of the Lower Troposphere during LEADDEX 92," in Proceedings of the Third Conference on Polar Meteorology and Oceanography, Portland, OR, 29 September - 2 October 1992.

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THESES DIRECTED: Rutherford, S.J., LT, USN, "Arctic Cyclones and Marginal Ice Zone (MIZ) Variability," Master's Thesis, March 1993.

Wos, K.A., LCDR, USN, "A Climatology of Polar Low Occurrences in the Nordic Seas and an Examination of Katabatic Winds as a Triggering Mechanism," Master's Thesis, December 1992.

OTHER: Guest, P.S., Davidson, K. L., Overland, J.E., and Frederickson, P.A., "Atmosphere-Ocean Interactions in the Marginal Ice Zones of the Nordic Seas," an invited paper accepted by Arctic Oceanography: Marginal Ice Zones and Continental Shelves, Walker Smith and Jackie Grebmeier, eds.

Guest, P.S., Glendening, J.W., and Davidson, K.L., "An Observational and Numerical Study of Wind Stress variations within Marginal Ice Zones," accepted by Journal of Geophysical Research.

Guest, P.S. and Davidson, K.L., "The Temperature and Energy Balance at the Marine Ice-Atmosphere Interface during the Polar Winter," submitted for Proceedings of the IAMAP-IAHS conference in Yokohama Japan, July 1993.

Guest, P.S. and Davidson, K.L., "Factors Affecting Variations of Snow Surface Temperature and Air Temperature over Sea Ice," accepted by the Nansen Centennial Symposium Volume on the Role of the Polar Oceans in Shaping the Global Environment.

DOD KEY TECHNOLOGY AREA: Environmental Effects.

KEYWORDS: Arctic, Leads, Atmospheric Forcing.

WIND/METEOROLOGICAL ANALYSES (NORCSEX '91)

K.L. Davidson, Professor

P.A. Frederickson, Physical Scientist

Department of Meteorology

**Sponsor: Naval Research Laboratory-Stennis Space Center,
(Code 321)**

Funding: Cost Share: NRL-SSC and NPS

OBJECTIVE: Goal is to obtain information on ERS-1 detected properties of ocean surface and air-sea interaction; accomplished by analyses/interpretations on in situ and regional meteorological data corresponding to the Norwegian Continental Shelf Experiment during November 1991 (NORCSEX '91) off the west Coast of Norway.

SUMMARY: The Norwegian Continental Shelf Experiment of 1991 (NORCSEX'91) was conducted off the west coast of Norway centered on Haltenbanken (64°30'N, 9°E) in November 1991 by collaborating scientists from Norway, USA, the UK, and France. NPS performed continuous measurements of the atmospheric surface layer and regular spaced measurements of the boundary layer profile. This was performed in collaboration with complementary shipboard and satellite retrieval studies by the Nansen Environmental and Remote Sensing Center (NERSC) and the Environmental Research Institute of Michigan (ERIM). Analyses were designed to demonstrate and validate ERS-1 capabilities of detecting: surface current frontal boundaries including eddies, near surface mesoscale wind field variations, and sea state conditions. Accomplishments through 1993, in addition to collecting the data were to reduce, edit, summarize and report collected in situ and regional analyzed meteorological data. Further, vector winds were

related to ERS-1 and shipboard obtained C-band radar backscatter.

PUBLICATIONS: Onstott, R.G. and Davidson, K.L., "Coastal Ocean Studies using Shipbased Scatterometer during NORCSEX'91," in Proceedings of the IGARSS'93, Toyko Japan, 18-21 August 1993.

Shuchman, R.A., Johannessen, J.A., Rufenach, C., Davidson, K.L., and Wackerman, C., "Determination of Wind Speed, Wind Direction and Atmospheric Structure using ERS-1 SAR Data during NORCSEX'91," in Proceedings of the IGARSS'93, Tokyo, Japan, 18-21 August 1993.

CONFERENCE PRESENTATIONS: Davidson, K.L., Onstott, R.G., and Ross, D., "Comparison of Surface wind Stress and Radar Backscatter variations with Bulk Wave-parameter Formulation Predictions," Invited paper, IAMAP-IAPSO Yokohama, Japan, 13-23 July 1993.

Davidson, K.L., Johannessen, J.A., and Shuchman, R.A., "Analysis and Interpretation of ERS-1 SAR detected Wind Rows Relative to Observed Air-Sea Interaction Processes," IAMAP-IAPSO, Yokohama, Japan, 13-23 July 1993.

OTHER: The following multi-authored papers that describe observed surface wind stress and radar backscatter

relationships are published or under review.

Davidson, K.L., Johannessen, J.A., Shuchman, R.A., and Brown, R.A., "Analysis and Interpretation of ERS-1 SAR detected Wind Rows Relative to Observed Air-Sea Interaction Processes," in Proceedings of Oceans '93, Victoria, British Columbia, Canada, 18-21 October 1993, III-19 to III-24.

Davidson, K.L., Frederickson, P.A., and Onstott, R.G., "Shipboard Studies of L-, C-, AND X-Band Backscatter and Surface Wind Forcing during NORCSEX '91," in Proceedings of the Oceans '93, Victoria, British Columbia, Canada, I-13 to I-19, 18-21 October 1993.

Weissman, D.E., Davidson, K.L., Brown, R.A., Friehe, C.A., and Li, F., "The Relationships Between the Microwave radar Cross Section and both the Wind Speed and Stress - Model Function Model Development Using FASINEX Data," Journal of Geophysical Research, in press.

Davidson, K.L., Onstott, R.G., Johannessen, J.A., Ross, D., Shuchman, R.A., Skagseth, O., and Skupniewicz, C.E., "Relationships Between Wind Stress and Radar Scatter and the Directional Wave Spectrum (NORCSEX'88)," submitted to The Atmosphere-Ocean System.

Frederickson, P.A., Davidson, K.L., Edson, J., and Taylor, P., "Comparisons of Ship and Tower Inertial Motion Estimates of the Surface Wind Stress," submitted to Journal of Atmospheric and Oceanic Technology.

DOD KEY TECHNOLOGY AREA:
Environmental Effects.

KEYWORDS: ERS-1, Wind Stress, Scatterometer, NORCSEX'91.

SINGLE POINT (SHIPBOARD) MEASUREMENTS AND SHAREM 102

K.L. Davidson, Professor

C.H. Wash, Professor

F.K. Jones, Physical Scientist

R.J. Lind, Meteorologist

Department of Meteorology

Sponsor and Funding: Naval Research Laboratory-Monterey Division

OBJECTIVE: Objectives are to 1) evaluate the influence on the ship presence on evaporation duct height estimates from bulk measurements, 2) establish/perform reconfiguration requirements for SSAWS, and 3) perform refractive condition outlook for SHAREM 102.

SUMMARY: NRL personnel and equipment participated in an experiment designed to determine surface target detection tactics is to evaluate shipboard measurement that would yield information of influencing refractive conditions. The experiment was in the Gulf of Oman and during the period from 3-12 January 1993. NPS evaluated data obtained from ship (R/V Point SUR) mounted surface layer meteorological sensor suite and radiosonde launches to establish approaches for configuration of measurements from

SHAREM 102 ship. A review was conducted of an existing portable instrumentation suite and acquisition system and developed deployment procedures relative to its suitability and adaptability for SHAREM 102. NPS

provided advice and consultation on what refractive conditions to expect in the zone of interest during the January period.

THESIS DIRECTED: Craigie, Kyle M., LCDR, USN, "Assessment of Atmospheric Influence on Surveillance Radar Performance in Littoral Zones," Master's Thesis, September 1993.

DOD KEY TECHNOLOGY AREA:
Environmental Effects, Sensors.

KEYWORDS: SHAREM 102, Evaporation Duct, Coastal, EM Wave Refraction.

METEOROLOGICAL SENSORS FOR SHAREM 102

K.L. Davidson, Professor

C.H. Wash, Professor

R.J. Lind, Meteorologist

F.K. Jones, Physical Scientist

Department of Meteorology

Sponsor and Funding: Naval Research Laboratory-Monterey Division

OBJECTIVES: Objectives in supporting SHAREM 102 (August 1993) are to 1) Establish/perform configuration requirements for SSAWS, and 2) Provide advice and direction on installation of equipments on the USN ship, USS Elliot.

SUMMARY: The tasks completed were to perform design and consultation on acquisition and display of atmospheric information as well as special analyses interpretation on shipboard data collected during SHAREM 102. Sharem 102 will occurred in August 1993 in the Gulf of Oman.

Instrumentation design and acquisition was for a west coast USN ship that will left for the upper Arabian Sea in early July 1993. NPS personnel assisted with installation at Portland. All efforts were performed in collaboration with NRL persons onboard the ship during SHAREM 102.

DOD KEY TECHNOLOGY AREA:
Environmental Effects, Sensors.

KEYWORDS: Atmospheric Boundary Layer, Satellite Sensing, Evaporation Duct.

METEOROLOGICAL STUDIES IN SHAREM 102

K.L. Davidson, Professor

C.H. Wash, Professor

R.J. Lind, Meteorologist

Department of Meteorology

Sponsor and Funding: Naval Research Laboratory-Monterey Division

OBJECTIVE: Objectives are to design and consult on shipboard acquisition/display of atmospheric information and to perform special analyses/interpretation on shipboard data collected during SHAREM 102.

SUMMARY: An extension to work described and carried out in NRL supported effort titled, "Meteorological Sensors for Sharem

102". Instrumentation design and acquisition were accomplished for a west coast USN ship that left for the upper Arabian Sea in July.

DOD KEY TECHNOLOGY AREA:
Environmental Effects, Sensors.

KEYWORDS: Atmospheric Boundary Layer, Satellite Sensing, Evaporation Duct.

REFRACTIVE DESCRIPTIONS THROUGH MEASUREMENTS

K.L. Davidson, Professor
Department of Meteorology

Sponsor: Space and Naval Warfare Command (SPANAR) PMW 165D

Funding: SPANAR PMW 165

OBJECTIVE: The objective is to perform special analyses AND interpretations and to provide advice and consultation on shipboard assessment of near-surface radar/radio refractive conditions.

SUMMARY: Refractive layer assessments with existing and planned shipboard measurement approaches for atmospheric surface layer and ocean surface properties were examined on the basis of flux-profile scaling models for the non-neutral atmospheric surface layers. In situ measured data for assessments have been identified. Scaling models applied to the near-surface region were based on one-level airflow, temperature and moisture and surface temperature mean (bulk) data with or without one-level turbulence data. Turbulence data will be related to

the fluxes using the inertial-dissipation method. Data considered were obtained from the R/V Point Sur in two FY93 experiments off the west coast. One experiment, in the vicinity of Monterey Bay during October 1992, includes ship and buoy data. A second experiment occurred in the California bight in August 1993 in conjunction with the VOCAR intensive collection period. JHU/APL personnel and equipment were onboard the research vessel and the resulting data will be compared with NPS obtained data.

DOD KEY TECHNOLOGY AREA:
Environmental Effects, Sensors.

KEYWORDS: Radar Refraction, Evaporation Duct, Marine Atmosphere Boundary Layer.

COASTAL REGION REFRACTIVE ASSESSMENTS AND HIS EVALUATION

K.L. Davidson, Professor

C.H. Wash, Professor

Department of Meteorology

**Sponsor: Naval Command Control and Ocean Surveillance Center,
RDT&E Division (NRaD), Code 54**

Funding: Cost share NRaD and NPS

OBJECTIVE: The goals of this project are 1) to obtain in situ ship/buoy measurements to characterize the humidity profile in the air layer adjacent to the sea, 2) to examine the value of different sensors (AVHRR, SSM/I) satellite information to describe evaporation duct variability, and 3) to evaluate the Ground-Based High-Resolution Interferometer Sounder (GB-HIS) as a refractive profile monitoring device. This is the first year of a continuing calibration/validation effort on assessment of refractive condition.

SUMMARY: Several procedures were carried out to evaluate and apply approaches for estimating overwater, and coastal refractive conditions. In situ and remote measurements were used along with different analyses approaches. Data collection occurred in vicinity of Monterey Bay during October 1992 and in the California bight during August 1993 to characterize refractive conditions and evaluate estimation procedures on basis of fused ship/buoy/satellite data sets. Bulk versus turbulent approaches for evaporation duct estimation were examined. Existing satellite-sensor retrievals were applied to estimation of near-

surface dryness for past NPS cruise periods that were cloud-free. Ship and buoy systems. Time-series of marine boundary layer obtained GB-HIS and radiosonde profiles were compared and statistical parameters of paired data sets were calculated with regard to RMS differences, bias, and the explained variance.

THESES DIRECTED: Rugg, Steve, CAPT, USAF," An Investigation of the Ground-Based High-Resolution Interferometer Sounder (GB-HIS) in a Coastal Marine Environment," Master's Thesis, December 1992.

Craigie, Kyle M., LCDR, USN, "Assessment of Atmospheric Influence on Surveillance Radar Performance in Littoral Zones," Master's Thesis, September 1993.

OTHER: Two theses are in progress with VOCAR data set; Ledesma, Roy, LT, USN, Dec 1993 and Walsh, David, LT, USN, June 1994.

DOD KEY TECHNOLOGY AREA:
Environmental Effects, Sensors.

KEYWORDS: Atmospheric Boundary Layer, Evaporation Duct, Coastal, EM Wave Refraction.

SAGE III SCIENCE TEAM

P. A. Durkee, Associate Professor
Department of Meteorology
Sponsor and Funding: National Aeronautics and
Space Administration

OBJECTIVE: The objectives during phase B of SAGE III development were to examine global aerosol distribution observations from NOAA AVHRR and SAGE I and II measurements and identify regions of potentially high aerosol-climate impact. Primary emphasis was on the upper tropospheric observations available from SAGE I and II. A second objective was to examine case studies of AVHRR-SAGE II comparisons. AVHRR aerosol optical depth was compared to profiles of extinction from SAGE II. Issues such as upper tropospheric cloud contamination were also considered. The goal of this work was to show the usefulness of analyses incorporating SAGE III observations with nadir views from high spectral and spatial resolution radiometers on EOS such as MODIS.

SUMMARY: Global summaries of aerosol optical depth have been prepared for April 1982-84 using NOAA-7 AVHRR. Features such as Saharan dust, continental plumes of anthropogenic pollution, and advected smoke from biomass burning were detected. Also apparent in these analyses was a distinct difference between optical depth in the northern and southern hemispheres. These results are consistent with SAGE I tropospheric results reported by Kent et al. (1988) and SAGE II results distributed by Kent to the SAGE III Science Team (unpublished). From these results it appears that much of the hemispheric differences observed in the total aerosol optical

depth from AVHRR measurements are due to upper tropospheric aerosols advected from continental sources (anthropogenic and terrestrial). Comparisons between SAGE II extinction profiles and AVHRR optical depth are in progress. Cases are being identified from April (peak in Asian dust transport across the Pacific) and July (Saharan dust cases) 1985. The phase C/D efforts will include continued comparison of AVHRR and SAGE II cases. Emphasis will be placed on sources responsible for long range aerosol transport at mid-tropospheric levels. Saharan and Gobi Desert dust events, pollution episodes in eastern Asia and northeastern US, and smoke from agricultural and natural burning will all be examined. To the extent that tropospheric aerosols are included in the SAGE III studies, this effort will investigate relationships between various aerosol optical depth regimes and cloud reflectance characteristics. These studies will include examination of multispectral radiative signatures of aerosol features and the impact of MODIS estimates of aerosol characteristics. Also in phase C/D, support of field measurement programs planned under the SAGE III effort will be provided using satellite-based measurements and analyses of spectral optical depth and aerosol transport. These observations will be applicable to real time aircraft operations and post-experiment analysis.

PUBLICATIONS: Durkee, P.A., Pfeil, F., Frost, E., and Shema, R. "Global Analysis of Aerosol Particle Characteristics and Implications for Effects on Climate," Atmospheric Environment, Vol. 25A, pp. 2457-2465, 1993. (Also supported by other projects).

DOD KEY TECHNOLOGY AREA:
Environmental Effects.

KEYWORDS: Satellite Remote Sensing,
Aerosols.

**SATELLITE STUDIES OF THE TRANSFORMATION DYNAMICS
OF MARINE AEROSOLS**

**P. A. Durkee, Associate Professor
Department of Meteorology**

Sponsor and Funding: Office of Naval Research

OBJECTIVE: Satellite observations of atmospheric aerosol particles will be used to study the transition of particle distributions in support of the ONR initiative on Transformation Dynamics of Marine Aerosols (TDMA). Studies will focus on parameterization techniques for Navy aerosol models and studies of aerosol distributions during ASTEX (Atlantic Stratocumulus Transition Experiment).

SUMMARY: Funding for this project began in April 1992. The highlights of accomplishments are threefold. First, participation in ASTEX during June 1992 in the Azores islands provided excellent validation data for aerosol retrievals and case studies of aerosol transitions. Satellite support of the aircraft-based aerosol transitions studies was begun. Second, M. Rouault completed a theoretical study of aerosol retrieval using NOVAM (Navy Oceanic Vertical Aerosol Model) and a complex radiative transfer model. The results are very encouraging for application of satellite retrieved parameters to NOVAM. Third, the

results of Rouault have been incorporated into our regional analysis scheme and summaries of the ASTEX region are proceeding.

PUBLICATION: Rouault, M. and Durkee, P.A., "Characterization of Aerosols above the Ocean from Satellite Remote Sensing," Nucleation and Atmospheric Aerosols, N. Fukuta and P. E. Wagner, eds., DEEPAK Publishing, pp 357-360, 1993.

CONFERENCE PRESENTATIONS: Durkee, P. A., Ruppe, K., and Skupniewicz, C., "Interactions between Continental Aerosols Particles and Marine Stratocumulus Clouds during ASTEX," AGU Spring Meeting, Baltimore, MD, 24-28 May 1993.

THESIS DIRECTED: Ruppe, K., "Aerosol-cloud interactions during ASTEX," Master's Thesis.

DOD KEY TECHNOLOGY AREA: Environmental Effects.

KEYWORDS: Satellite Remote Sensing, Aerosols, Marine Boundary Layer, Aerosol-Closed Interaction.

STUDIES OF THE EFFECTS OF SHIP ACTIVITY ON CLOUD PROPERTIES

P. A. Durkee, Associate Professor

Department of Meteorology

Sponsor and Funding: Office of Naval Research

OBJECTIVE: Satellite observations of ship tracks in stratiform clouds will be analyzed and compared to meteorological and aircraft measurements. Phenomenological studies will define the physical, temporal and radiative characteristics of tracks including occurrence statistics. Mechanism studies will incorporate aircraft measurements to begin to determine formation processes.

SUMMARY: Funding for this project began in April 1992. Extensive results from a number of thesis projects are complete. Salvato compared high latitude ship track formation with subtropical regions and found that the Arctic region is significantly more susceptible to track formation. Pettigrew developed the most complete set of ship-ship track collocations to date. It was determined that the ship is typically within 5-10 km of the track head. Evans compiled a set of 60 tracks and analyzed them for physical and radiative characteristics. Giampaolo tested an automated track detection algorithm developed by Nielsen. Lutz completed a study of occurrence statistics for tracks in the eastern North Pacific and showed that tracks are more common than previously thought. Millman developed an analysis technique that allows study of the temporal characteristics of tracks and showed that the dispersion characteristics of tracks are as expected from turbulence models.

During the summer of 1993 data was collected off the US west coast. Approximately 5000 tracks are included in the data set. Extraction of track characteristics is progressing. A thesis by Mays (1993) describes the design of a database approach to analysis of large numbers of shiptracks.

CONFERENCE PRESENTATIONS:

Kuciauskas, A., Durkee, P.A., Skupniewicz, C., and Nielsen, K.E., "Radiative Characteristics of Shiptracks at Night," Cloud Impacts on DOD Operations and Systems (CIDOS-93), Fort Belvoir, VA, 16-19 November 1993.

Durkee, P.A., Kuciauskas, A., Skupniewicz, C., and Nielsen, K.E., "Investigations of Shiptracks in Marine Clouds," Cloud Impacts on DOD Operations and Systems (CIDOS-93), Fort Belvoir, VA, 16-19 November 1993.

OTHER: Twohy, C.H., Durkee, P.A., Huebert, B.J., and Charlson, R.J., "Effects of Aerosol Particles on Droplet Size Distributions and Satellite-Derived Reflectance in Coastal Stratiform Clouds," submitted to Journal of Geophysical Research.

Porch, W., Kao, C.-Y. J., Buchwald, M., Unruh, W., Durkee, P.A., Hindman, E., and Hudson, J., "The Effects of External Forcing on the Marine Boundary Layer: Ship Trails and a Solar Eclipse," submitted to Atmospheric Environment.

Hindman, E.E., Porch, W.M., Hudson, J.G., and Durkee, P.A., "Ship-Produced Cloud Lines of 13 July 1991," submitted to Atmospheric Environment.

THESES DIRECTED: Salvato, G.S., "Comparison between Arctic and Sub-tropic Ship Exhaust effects on Cloud Properties," Master's Thesis, 1992.

Pettigrew, J.C., "Surface Meteorological Parameters of Identified Ship Tracks," Master's Thesis, September 1992.

Evans, M.E., "Analysis of Ship Tracks in Cloudiness Transition Regions," Master's Thesis, September 1992.

Lutz, J.W., "Ship Tracks: A Geographical and Statistical Study," Master's Thesis, December 1992.

Mays, D., "Shiptrack Database Analysis," Master's Thesis, December 1993.

Millman, T.M., "A Temporal Analysis of East Pacific and East Atlantic Ship Tracks," Master's Thesis, December 1992.

Giampaolo, V.F., "Shiptrack Detection Algorithm Study," Master's Thesis, June 1992.

DOD KEY TECHNOLOGY AREA:
Environmental Effects.

KEYWORDS: Satellite Remote Sensing, Aerosol-Closed Interaction, Shiptracks, Marine Boundary Layer.

CLOUD-CLIMATE FEEDBACK MECHANISMS:
IMPACT OF REDUCTION IN FOSSIL FUEL EMISSIONS

P. A. Durkee, Associate Professor
Department of Meteorology
Sponsor and Funding: Department of Energy

OBJECTIVE: Analysis of satellite observations of cloud radiative properties will be conducted by NPS in conjunction with North Carolina State University measurements at the Mount Mitchell research facility.

SUMMARY: Analysis procedures were set up from data collected during summer 1993. Data collected at Mt. Mitchell was used to identify case

studies. Preliminary results indicate clouds over land can be analyzed for microphysical effects of aerosols. These results will be presented in Saxena et al. (1994).

DOD KEY TECHNOLOGY AREA: Environmental Effects.

KEYWORDS: Data Collection, Clouds.

SHIPBOARD AND SATELLITE INVESTIGATIONS OF
MARINE AEROSOL PARTICLES

P. A. Durkee, Associate Professor
Department of Meteorology
Sponsor and Funding: National Aeronautics and
Space Administration

OBJECTIVE: Analysis of satellite observations of aerosol and cloud radiative properties will be conducted by NPS in conjunction with NOAA PMEL research cruises and the ACE-1 experiment.

SUMMARY: Data was collected during two cruises of the NOAA ship Surveyor. During April/May 1993, data was collected aboard the Surveyor from Tahiti to Seattle and during November/December 1993, data was collected on a reverse track from Seattle to Tahiti.

This satellite data is being analyzed for aerosol properties related to ship-board measurements. Hemispheric and region variations are evident in the data and the results will provide open ocean analysis of marine aerosol formation and transport mechanisms.

DOD KEY TECHNOLOGY AREA: Environmental Effects.

KEYWORDS: Data Collection, Satellites.

TROPICAL CYCLONE MOTION STUDIES

R. L. Elsberry, Professor

P. A. Harr, Adjunct Professor

L. E. Carr, III, Assistant Professor

Department of Meteorology

Sponsor and Funding: Office of Naval Research

OBJECTIVE: The objective of this continuing project is to improve understanding of synoptic-scale, mesoscale and large-scale environmental influences on tropical cyclone motion. A long-term goal is to improve the accuracy of tropical cyclone track predictions for the Fleet as well as to extend the period of skillful track forecasts from 72 h to 120 h.

SUMMARY: A summary (Elsberry 1993) of the advances in dynamical prediction of tropical cyclone motion was prepared. An overview of the tropical cyclone hazards has been published (Holland and Elsberry 1993). Decomposition of the preliminary TCM-90 wind fields into three components has been tested (Elsberry and Bohner 1993). Application of the decomposition technique to the high-resolution TCM analyses resulted in propagation vectors that were realistic in magnitude, but more equatorward than in prior studies (Elsberry, Dobos and Titley 1993).

Dunnavan et al. (1993), McKinley and Elsberry (1993) and Boothe et al. (1993) have described preliminary results from the Tropical Cyclone Motion (TCM-92) mini-field experiment. Unique observations of tropical mesoscale convective systems have been obtained, and the relationships of these systems to tropical cyclone motion and formations are being studied.

Carr and Elsberry (1993) have modelled the interaction of a tropical cyclone with a monsoon gyre that leads to sudden track changes. Harr and Elsberry (1993) have studied still larger scale circulations that control both active vs. inactivity of the tropical cyclones in the western Pacific, and also whether the track will be a straight-mover or a recurver. Work in progress is to understand the predictability of this large-scale interaction and to explore long-range predictions of track type.

A field program summary (Harr et al. 1993) of the TCM-93 mini-field experiment has been prepared. In addition to summarizing the highlights of the seven missions, the data sets are described for potential use by other researchers.

PUBLICATIONS: Elsberry, R.L. and Bohner, R.H., Jr., "Three-component Decompositions of Tropical Cyclone Wind Fields: Relation to Tropical Cyclone Motion," in Tropical Cyclone Disasters, Lighthill, J., Zhemine, Z., Holland, G., and Emanuel, K., eds., Peking University Press, pp. 306-317, 1993.

Holland, G.J. and Elsberry, R.L., "Tropical Cyclones as Natural Hazards: A Challenge for the IDNDR," in Tropical Cyclone Disasters, Lighthill, J., Zhemine, Z., Holland, G., and Emanuel, K., eds., Peking University Press, pp. 17-30, 1993.

Harr, P.A. and Chen, J.-M., "Interpretation of Extended Empirical Orthogonal Function (EOF) Analysis," Monthly Weather Review, Vol. 121, No. 9, pp. 2631-2636, September 1993.

Boothe, M.A., Harr, P.A., and Elsberry, R.L., "Interaction Between a Mesoscale Convective System and the Large-scale Monsoon Flow during TCM-92," preprints of the 20th Conference on Hurricanes and Tropical Meteorology, American Meteorological Society, San Antonio, TX, pp. 481-484, May 1993.

Carr, L.E., III and Elsberry, R.L., "Barotropic Modelling of Monsoonal Interactions Leading to Sudden Track and Structure Changes of Tropical Cyclones," Preprints of the 20th Conference on Hurricanes and Tropical Meteorology, American Meteorological Society, San Antonio, TX, pp. 361-364, May 1993.

Dunnavan, G.M., Elsberry, R.L., Harr, P.A., McKinley, E.J., and Boothe, M. A., "Overview of the Tropical Cyclone Motion-92 Mini-field Experiment," Preprints of the 20th Conference on Hurricanes and Tropical Meteorology, American Meteorological Society, San Antonio, TX, pp. 477-480, May 1993.

Elsberry, R.L., Dobos, P.H., and Titley, D.W., "Extraction of Large-scale Environmental Flow Components from the TCM-90 Analyses: Implications for Tropical Cyclone Motion Studies," Preprints of the 20th Conference on Hurricanes and Tropical Meteorology, American Meteorological Society, San Antonio, TX, pp. 485-488, May 1993.

Harr, P.A. and Elsberry, R.L., "Variability of Tropical Cyclone Track Characteristics and Large-scale

Circulation Regimes over the Western Pacific Ocean," Preprints of the 20th Conference on Hurricanes and Tropical Meteorology, American Meteorological Society, San Antonio, TX, pp. 97-101, May 1993.

McKinley, E.J. and Elsberry, R.L., "Observations during TCM-92 of the Role of Tropical Mesoscale Convective Systems in Tropical Cyclogenesis," Preprints of the 20th Conference on Hurricanes and Tropical Meteorology, American Meteorological Society, San Antonio, TX, pp. 401-404, May 1993.

Carr, L.E., III and Elsberry, R. L., "Forecaster Rapporteur Report on Tropical Cyclone Motion," Technical Report WMO/TD No. 573, World Meteorological Organization, pp. 67-91, Geneva, 1993.

Elsberry, R.L., "Advances in Dynamical Predictions and Modeling of Tropical Cyclone Motion," NPS Technical Report NPS-MR-93-002, March 1993.

Harr, P.A., Elsberry, R.L., Ritchie, E.A., Willoughby, H.W., Boothe, M. A., Carr, L.E., III, and Jeffries, R. A., "Tropical Cyclone Motion (TCM-93) Field Experiment Summary," NPS Technical Report NPS-MR-93-004, October 1993.

CONFERENCE PRESENTATIONS: Carr, L. E., III and Elsberry, R.L., "A Systematic Approach to Tropical Cyclone Forecasting in the Western Pacific Region," USPACOM Tropical Cyclone Conference, Tokyo, Japan, February 1993.

Elsberry, R.L., "Outlook for Tropical Cyclone Track Predictions," Annual Meeting American Meteorological Society, Anaheim, CA, January 1993.

Elsberry, R.L., "Tropical Cyclone Research at the Naval Postgraduate School," USPACOM Tropical Cyclone Conference, Tokyo, Japan, February 1993.

Elsberry, R.L., "Preliminary Results from the 1992 Mini-field Experiment," USPACOM Tropical Cyclone Conference, Tokyo, Japan, February 1993.

Elsberry, R.L., "1992 Guam Mini-field Experiment," 47th Interdepartmental Hurricane Conference, Miami, FL, February 1993.

Elsberry, R.L., "Advances in Tropical Cyclone Motion Understanding and Prediction with Dynamical Models," International Association Meteorology and Atmospheric Physics Symposium, Yokohama, Japan, July 1993.

Elsberry, R.L., "Tropical Cyclone Motion," Third International Workshop on Tropical Cyclones, Huatulco, Mexico, November 1993.

Harr, P.A. and Elsberry, R.L., "Predictability of Western North Pacific Tropical Cyclone Characteristics Associated with Large-scale Circulation Regimes," International Association Meteorology and Atmospheric Physics Symposium, Yokohama, Japan, July 1993.

DOD KEY TECHNOLOGY AREA:
Environmental Effects.

KEYWORDS: Tropical Cyclone Motion, Tropical Cyclone Formation, Tropical Mesoscale Convective Systems.

TROPICAL CYCLONE PREDICTION

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P.A. Harr, Adjunct Professor

Sponsor: Office of Naval Research (1122MM)

Department of Meteorology

Funding: Naval Postgraduate School

OBJECTIVE: The long-term goal of this continuing project is to improve predictions of tropical cyclone motion.

SUMMARY: An observational and numerical study of the orographically-induced effects for tropical cyclones approaching Taiwan from the east has been completed (Yeh and Elsberry 1993a, b, c, d). Upstream track deflections are found in two regions. At first, the deflections are southward and eastward in response to an enhanced barrier effect as the outer cyclone circulation approaches. Closer to the barrier, the inner core circulation is greatly distorted and an cyclonic (anticyclonic) asymmetric circulation forms over (offshore from) the orography. It is the flow between these counter-rotating gyres that cause the northward and eastward track deflections for cyclones approaching the southern portion of Taiwan (Yeh and Elsberry 1993b).

The numerical simulations reproduce the observed tendency for northern-approaching storms to pass continuously around or over Taiwan orography, whereas southern-approaching storms are more likely to have discontinuous tracks (Yeh and Elsberry 1993c). More intense or rapidly translating storms tend to have more direct and continuous tracks across the barrier. The surface pressure and wind centers become decoupled as the storm

dissipates on the upstream side, and these centers may move in opposite directions.

Dobos and Elsberry (1993) have evaluated the accuracy of tropical cyclone recurvature for three objective track techniques and the official forecasts of the Joint Typhoon Warning Center during 1979-1984. The One-way influence Tropical Cyclone Motion is the most accurate. Ford et al. (1993) have developed an objective recurvature prediction technique that has skill relative to the objective techniques.

PUBLICATIONS: Dobos, P.H. and Elsberry, R.L., "Forecasting Tropical Cyclone Recurvature - Part I, Evaluation of Existing Methods," Monthly Weather Review, Vol. 121, No. 5, pp. 1273-1278, May 1993.

Ford, D.M., Elsberry, R.L., Harr, P. A., and Dobos, P.H., "Forecasting Tropical Cyclone Recurvature - Part II, An Objective Technique using an Empirical Orthogonal Function Representation of Vorticity Fields," Monthly Weather Review, Vol. 121, No. 5, pp. 1279-1290, May 1993.

Yeh, T.-C. and Elsberry, R.L., "Physical Processes Involved in Typhoon Track Deflections Caused by Taiwan Orography," East Asia and Western Pacific Meteorology and Climate II, World Scientific Publishers, Singapore, pp. 213-222, 1993.

Yeh, T.-C. and Elsberry, R.L.,
"Interaction of Typhoons with the
Taiwan Orography - Part I, Upstream
Track Deflections," Monthly Weather
Review, Vol. 121, No. 12, pp. 3193-
3212, December 1993.

Yeh, T.-C. and Elsberry, R.L.,
"Interaction of Typhoons with the
Taiwan Orography - Part II,
Continuous and Discontinuous Tracks
Across the Island," Monthly Weather
Review, Vol. 121, No. 12, pp. 3213-
3233, December 1993.

Yeh, T.-C. and Elsberry, R.L.,
"Numerical Simulation Study of
Typhoons Crossing Taiwan," in
Proceedings of the Conference on
Weather Analysis and Forecasting,
Taipei, Taiwan, pp. 323-330, May
1993.

CONFERENCE PRESENTATIONS: Elsberry,
R.L. and Yeh, T.-C., "Interaction of
Tropical Cyclones with Orography:
Continuous versus Discontinuous
Tracks Across Taiwan," International
Association Meteorology and
Atmospheric Physics Symposium,
Yokohama, Japan, July 1993.

DOD KEY TECHNOLOGY AREA:
Environmental Effects.

KEYWORDS: Tropical Cyclone Motion,
Tropical Cyclone Recurvature,
Tropical Cyclone Track Prediction.

**FEASIBILITY STUDY OF A WEST COAST PICKET FENCE SPECIFICATION
OF UPSTREAM BOUNDARY CONDITIONS FOR STORM**

R. L. Elsberry, Professor

P. A. Hirschberg, Adjunct Professor

R. J. Lind, Meteorologist

Department of Meteorology

Sponsor and Funding: National Science Foundation

OBJECTIVE: The basic objective of this continuing project is to demonstrate that a "picket fence" of extra rawinsonde stations along the U.S. west coast will improve the time and spatial resolution of the mass, momentum, heat, kinetic energy and moisture carried by jet streaks and short waves entering the U.S. from the data-sparse Pacific Ocean. A consequence of this improved specification of the "upstream boundary" conditions will be a more accurate forcing of the mesoscale weather systems that develop over the central U.S.

SUMMARY: The feasibility of this concept was tested during the STORM-Fronts Experiment Systems Test (FEST) during 1 February to 15 March 1992. A series of seven special rawinsonde sties were interspersed among the seven regular rawinsonde sites along the west coast from Port Hardy, British Columbia to San Diego, California. In addition to the improved spatial resolution, rawinsondes were launched every 3 h at all 14 sites to improve the time resolution during four Intensive Observing Periods (Lind et al. 1992). Data from the regular and special sites have been collected, put into a

common format and delivered to the STORM-FEST Data Management Center and to the participants. An extensive quality control of the observations in the vertical, and via time and spatial cross-sections along the west coast, has been completed. Preliminary analyses indicate that the enhanced observations captured features that would have been poorly sampled by the conventional 12-h rawinsonde network along the west coast. A M.S. thesis in progress is objectively analyzing the soundings to a regular grid. Diagnostic calculations of momentum, heat, kinetic energy and moisture fluxes will be compared with and without the special picket fence observations.

PUBLICATION: Lind, R.J., Hirschberg, P.A., Titley, D.W., and Elsberry, R. L., "West Coast Picket Fence Feasibility Study during STORM-FEST. I., Field Program Summary," NPS Technical Report NPS-MR-92-003, July 1992.

DOD KEY TECHNOLOGY AREA:
Environmental Effects.

KEYWORDS: Boundary Fluxes, Data Impacts, Mesoscale Weather Systems.

STRUCTURE AND DYNAMICS OF COASTAL OCEAN FILAMENTS (EBC/ARI)

R.L. Haney, Chairman & Professor

Department of Meteorology

Sponsor: Office of Naval Research

Funding: Office of Naval Research, Code 322PO

OBJECTIVE: The broad objective of this research is to explore the structure and dynamics of cold filaments over the continental rise and slope in eastern boundary current regions using model-data assimilation. A multi-level primitive equation ocean model, and data from the EBC hydrographic/ADP surveys, will be used to address questions about the observed filaments that can not be answered with the data alone.

SUMMARY: Since this is a new project, the data assimilation studies are in progress at the present time. Our approach is to use static data assimilation and dynamic initialization to determine the best estimate of the structure and currents of coastal ocean filaments at the time of each EBC hydrographic survey in the California Current. The resulting fields will be used to test the following hypotheses: (1) the 3-D circulation in coastal jets and filaments departs significantly from quasi-geostrophic (QG) theory

due to nonlinearity, (2) strong vertical circulations occur at entrance and exit regions of coastal jets, (3) strong vertical circulations occur between crests and troughs of meandering coastal jets, and (4) the vertical circulations associated with these features extend deep enough to transport biota and other trace material out of the surface layer and into the deeper ocean.

CONFERENCE PRESENTATION: Haney, R. L., "Dynamic Initialization in the California Current using a digital filter," 25th International Liege Colloquium on Ocean Hydrodynamics, Liege, 3-7 May 1993.

OTHER: Chumbinho, Rogerio, P., LT, PT NAV, Ph.D. Dissertation, in progress; Graduation Dec. 1994.

DOD KEY TECHNOLOGY AREA: Environmental Effects.

KEYWORDS: Ocean Data Assimilation, Coastal Ocean Dynamics.

DIGITAL FILTER INITIALIZATION IN THE OCEAN

R.L. Haney, Chairman & Professor

Department of Meteorology

Sponsor: Office of Naval Research

Funding: Office of Naval Research, Code 124

OBJECTIVE: This research is to test and verify a new method of initializing a primitive equation model of the coastal oceans. The initialization method, referred to as Digital Filter Initialization (DFI), was recently developed by Lynch and Huang (1992) for use in an intermittent data assimilation system in the atmosphere. The DFI method consists of applying a digital filter to time series of model variables generated by short term backward and forward integrations starting from an uninitialized analysis. The objective of this study is to examine the performance of the DFI method in controlled numerical experiments in the coastal oceans.

SUMMARY: Since this is a new project, the work has just started. The DFI method will be developed and verified in increasingly complex numerical ocean experiments. The first of such experiments will utilize idealized neutral baroclinic wave modes, for which the dynamically adjusted state is known analytically, as a reference solution. The DFI method will then be used to recover (i.e., to initialize) the three dimensional currents in the reference solution starting from the initial density field alone. In these

experiments, the DFI method will be optimized and subsequently verified as a function of the baroclinic wave scale. This will establish the skill of the DFI method in the linear quasi-geostrophic regime. A following set of experiments will examine the DFI method in the context of a realistic spectrum of nonlinear finite amplitude coastal ocean disturbances. The performance of the method, specifically its ability to recover the divergent part of the circulation, will be quantitatively verified. The results of this research will contribute to better initialization of coastal ocean prediction models and to an improved representation and understanding of the three-dimensional circulation associated with mesoscale features observed in the coastal oceans.

CONFERENCE PRESENTATION: Haney, R. L., "Dynamic Initialization in the California Current using a Digital Filter," 25th International Liege Colloquium on Ocean Hydrodynamics, Liege, 3-7 May 1993.

DOD TECHNOLOGY AREA: Environmental Effects.

KEYWORDS: Ocean Data Assimilation, Coastal Ocean Dynamics.

**ESTIMATING SUBPYCNOCLINE DENSITY FLUCTUATIONS IN THE CALIFORNIA
COASTAL REGION FROM UPPER OCEAN OBSERVATIONS**

**Robert L. Haney, Chairman & Professor
Department of Meteorology**

Sponsor: Office of Naval Research

Funding: Office of Naval Research, Code 124

OBJECTIVE: The objective of this study is to test and verify a method for estimating density fluctuations in and below the ocean pycnocline from observations in the upper ocean alone.

SUMMARY: The problem being considered is that of constructing the best estimate for the density profile below a certain depth D , given the observed density profile above that depth. For this purpose, the estimated disturbance profile is modeled as a weighted sum of the first N empirical vertical modes (EOFs). For each observed density profile, the EOF weights that determine the estimated profile are obtained by performing a successive least squares fit of the disturbance density profile above D to the first N EOFs. In this study, N is taken to be 7, which is the number of EOFs considered necessary to account for the "signal" in the profiles as determined by the methods of Preisendorfer et al. (1981) and Smith et al. (1985). The estimated profiles are then verified against the observed profiles to 2000 m, and the results are presented as a function of the depth D .

In general, the vertical extension method is moderately successful at estimating density fluctuations at and below 500 m from data entirely above 500 m. The correlations between the estimated profiles and a

7-mode reconstruction of the observed profiles, representing the observed "signal," are somewhat higher. A practical result of this study is that data down to only 200 m, as might be acquired by a SEASOAR CTD survey, can estimate the "signal" part of the density fluctuations at 500 m with a correlation of .47 in summer and .69 in winter.

OTHER: Haney, R.L., Hale, R. A., and Collins, C.A., "Estimating Subpycnocline Density Fluctuations in the California Current Region from Upper Ocean Observations," NPS Technical Report, in progress.

Haney, R.L., Hale, R.A., and Collins, C. A., "Estimating Subpycnocline Density Fluctuations in the California Current Region from Upper Ocean Observations," to be submitted to Journal of Atmospheric Oceanic Technology, January 1994.

Haney, R. L., Hale, R.A., and Collins, C.A., "Estimating Subpycnocline Density Fluctuations in the California Current Region from Upper Ocean Observations," 1994 Ocean Sciences Meeting, San Diego, CA, 21-24 February 1994, forthcoming.

DOD KEY TECHNOLOGY AREA:
Environmental Effects.

KEYWORDS: California Current,
Vertical Empirical Orthogonal
Function (EOF) Analysis.

**DIABATIC EFFECTS ON EXTRATROPICAL CYCLONE INTENSIFICATION AND
MOTION OVER COASTAL AND MARITIME REGIONS**

P. A. Hirschberg, Assistant Research Professor

C. H. Wash, Professor

Department of Meteorology

Sponsor: Office of Naval Research

Funding: Naval Postgraduate School

OBJECTIVE: The objective of this continuing project is to examine how diabatic effects act to alter the intensification and motion of rapidly deepening extratropical cyclones over coastal and maritime regions. The study focuses on a rapidly developing coastal cyclone observed during the Experiment on Rapidly Intensifying Cyclones over the Atlantic (ERICA), and utilizes observations and simulations of the event with the Navy Operational Regional Atmospheric Prediction System (NORAPS).

SUMMARY: Two M.S. theses were completed that documented the synoptic and mesoscale evolution of ERICA 5A. Several processes including strong lower-tropospheric temperature advection and upper-level cyclonic vorticity advection and divergence were found to contribute to the intense development of the storm. The efficacy of a 36-h NORAPS full physics forecast of the event was also investigated. In general, this 60-km experiment produced a good simulation. In particular, it was found that NORAPS was able to represent the complex frontal evolution associated with the cyclogenesis. However, slight errors in the position and depth of the sea level cyclone became evident by the end of the simulation. Subjective hand analyses of hourly operational and special experiment data for the period surrounding the onset of rapid deepening, revealed the presence of a mesoscale coastal cyclone not resolved by the model. It is hypothesized that this mesoscale

cyclone affected the development of ERICA 5A and resulted in the track and intensification errors in the model simulation of the event. A higher horizontal resolution run of NORAPS is planned to investigate this feature. In addition, the full physics simulation will be compared to a dry simulation to study the effects of diabatic processes.

PUBLICATIONS: Hirschberg, P.A. and Fritsch, J.M., "An Analytic Modeling Study of the Development of Extratropical Cyclones, Part I: The Effects of Stratospheric Structure," Journal of the Atmospheric Sciences, Vol. 50, No. 2, pp. 311-327.

Hirschberg, P.A., and Fritsch, J.M., "The Stratospheric Lid and Understanding Height Tendency," Monthly Weather Review, Vol. 121, No. 9, pp. 2646-2661.

CONFERENCE PRESENTATION: Hirschberg, P.A., "Tropopause Undulations and the Development of Extratropical Cyclone or Sutcliffe/Pettersen Development Theory Revisited," Eighth Extratropical Cyclone Workshop, Val-Morin, Quebec, 12-16 October 1992.

THESES DIRECTED: Spinelli, J. M., LT, USN, "An Investigation of the ERICA IOP-5A Cyclone," Master's Thesis, December 1992.

Cameron, S.R. LCDR, USN, "Mesoscale Frontal Evolution of the ERICA IOP-5A Cyclone," Master's Thesis, September 1993.

DOD KEY TECHNOLOGY AREA: Environ-
mental Effects.

KEYWORDS: Extratropical Cyclones,
Numerical Models Diagnostics.

COASTAL ATMOSPHERIC MESOSCALE MODELING STUDIES

T.R. Holt, Assistant Professor

Department of Meteorology

Sponsor and Funding: Naval Postgraduate School

OBJECTIVE: The research objective of this two year project was to investigate and evaluate important coastal mesoscale processes. The primary tasks performed were numerical simulations using the NPS/NRL mesoscale model under varying synoptic and coastal flows and use of these simulations to aid in the investigation and identification of important coastal physical processes.

SUMMARY: Mesoscale numerical simulations using the NPS/NRL model along the West Coast of the United States examined the 2-3 May 1990 case study. Model simulations incorporating explicit cloud liquid water and cloud/radiative processes were performed during year two (FY94). Results indicated that the updated model with the cloud liquid water and radiative/cloud parameterizations yielded more accurate simulations as verified from synoptic, mesoscale and satellite observations than simulations without radiative/cloud effects. There existed a strong interaction of topographically enhanced mesoscale subsidence and the formation of stratus along the central California coast. Convection primarily along the Sierra Nevada range agreed well with satellite imagery. The evolution of a boundary layer jet along the northern California coast, possibly caused by supercritical flow, was documented in mesoscale simulations.

Simulations using the NPS/NRL model for East Coast studies concentrated on diabatic effects without cloud liquid water or cloud/radiative

parameterizations. Results from numerous sensitivity experiments indicated the importance of proper timing of diabatic processes to provide in-phase forcing necessary for coastal cyclogenesis.

PUBLICATION: Holt, T.R. and Chang, S.W., "A Numerical Investigation of the Effects of Timing of Diabatic Processes in the Coastal Cyclogenesis of GALE IOP 2," Monthly Weather Review, 121, pp. 1007-1029.

THESIS DIRECTED: Fernandez, Damacene V., LCDR, USN, "Incorporation and Comparative Evaluation of a Non-Convective Cloud Parameterization Scheme in the Naval Research Laboratory West Coast Mesoscale Weather Prediction Model," Master's Thesis, June 1993.

OTHER: A journal article entitled "Structure of a trapped mesoscale disturbance along the central coast of California" by T.R. Holt has been submitted to Monthly Weather Review. A conference abstract entitled "Numerical simulations of the cloud-radiative and marine boundary layer interaction for a weak southerly surge event along the California coast" by T.R. Holt has been submitted to the Tenth Conference on Numerical Weather Prediction, Portland, OR, 17-22 July 1994. An NPS Master's Thesis entitled "Visualization of a Coastal Mesoscale Model" by LT R. Mark Sampson, USN, December 1993 (Second Reader) utilized the NPS/NRL West Coast model simulations.

DOD KEY TECHNOLOGY AREA: Environmental Effects.

KEYWORDS: Numerical Weather Prediction, Coastal Meteorology, Cloud-radiative Interactions.

MODELING OF ATMOSPHERIC MESOSCALE PROCESSES

**T.R. Holt, Assistant Professor
Department of Meteorology**

Sponsor and Funding: Naval Research Laboratory

OBJECTIVE: The research objective of this project was to improve physical parameterizations appropriate for coastal applications in the NPS/NRL mesoscale model. Specific tasks include the development and evaluation of an explicit cloud liquid water parameterization for nonconvective and convective clouds and an integrated cloud fractional-radiation scheme. Additional numerical simulations to assess the impact of assimilation of important latent heating derived from convective and nonconvective rainfall on coastal cyclogenesis was investigated.

SUMMARY: Incorporation of an explicit cloud liquid water scheme was completed in a triple nest version of the NPS/NRL mesoscale numerical model. Simulations to assess the importance of the interaction of cloud liquid water and radiative effects were performed for several geographic locations. Simulations along the West Coast of the United States where stratiform clouds predominate were performed to investigate the important cloud/radiative interactions for a marine boundary layer capped by nonconvective clouds. Results stress the importance of low level wind flow influenced by the complex coastal topography in influencing the

formation and movement of the marine stratus deck. Simulations in the tropical West Pacific were performed to investigate cloud/radiative interactions in a highly convective marine environment. Results indicate the importance of liquid water loading in affecting the water budget as well as in influencing the mesoscale circulation of intense convective updrafts and more spatially broad downdrafts.

Additional numerical simulations to investigate the impact of assimilation of rainfall rates on development and intensification of coastal and oceanic cyclogenesis were performed. Sensitivity experiments for the ERICA IOP-4 case study suggest that the dynamic processes are more responsible for the evolution and structure of the marine cyclone than the physical processes. The physical processes cooperate primarily in a nonlinear manner to intensify the storm.

OTHER: A journal article entitled "Impact of assimilating SSM/I rainfall rates on numerical prediction of wintertime cyclones" by S.W. Chang and T.R. Holt will appear in the January 1994 issue of Monthly Weather Review. A journal article entitled "A numerical study of the ERICA IOP-4 marine cyclone" by S.W.

Chang and T.R. Holt has been submitted to Monthly Weather Review.

DOD KEY TECHNOLOGY AREA:
Environmental Effects.

KEYWORDS: Numerical Weather
Prediction, Coastal Meteorology,
Cloud-radiative Interactions.

GLOBAL AND TROPICAL CIRCULATIONS

T. Murphree, Research Assistant Professor

C.-P. Chang, Professor

J.M. Chen, Research Assistant Professor

Department of Meteorology

Sponsor and Funding: Naval Research Laboratory

OBJECTIVE: This continuing project is designed to: (1) identify the dominant mechanisms of short term climate change in the atmosphere and ocean; (2) evaluate the tropical atmosphere and ocean systems produced by operational analyses and forecasts; and (3) improve atmosphere and ocean forecast systems.

SUMMARY: We have pursued five main research topics during 1993. These studies were conducted in collaboration with several colleagues; in particular, Dr. R. Gelaro and Dr. C. Reynolds of NRL-Monterey, and Ms L. Zambresky of FNOG.

We used both analyzed fields and the Navy Operational Global Atmospheric Prediction System (NOGAPS) model to identify the mechanisms which govern variability in the midlatitude responses to tropical thermal forcing. Our focus was on the sensitivity of the midlatitude response to intra-seasonal variations in the ambient flow. We confirmed that in both the analyzed and model fields, the waveguiding and barotropic instability characteristics of the subtropical jets may be major factors governing the response. These fluctuations in the subtropical jets may help explain why the response to a tropical heating event (e.g., the 1991-1994 El Niño event) may vary considerably during the course of an individual tropical event.

We have also continued our studies of jet fluctuations using additional analyzed and modeled fields. The East

Asian - North Pacific jet was found to be well correlated, at two major locations, with the tropical heating in the central and eastern Indian Ocean area and the western and central Pacific area. The NOGAPS model correlations were similar to, but generally weaker than, those in the analyzed fields. The results of this and the previously described topic suggest that tropical heating may exert much of its influence on the midlatitudes by first interacting with and modifying the midlatitude jet.

We have also continued our series of experimental NOGAPS forecasts on the global impacts of individual western Pacific typhoons. Our procedure involved selectively applying various versions of the NOGAPS tropical cyclone bogus procedure, including a negative bogus that effectively eliminates individual cyclones. During the past year we have experimented with two additional typhoons. We found that the impact of a single typhoon on the circulation over the North Pacific-North America-North Atlantic region may be significant. The dynamics of the typhoon's impacts are similar to those produced by larger and longer more persistent tropical heating events (e.g., El Niños). In particular, the waveguiding and instability features of the midlatitude jet play a key role in modulating the storm's effects.

Our fourth main research activity was the continuing analysis of equatorial Pacific air-sea interactions during

the 1991-1992 El Niño event. In the observational part of this study, we analyzed surface atmosphere and upper ocean data from an array of equatorial Pacific buoys. We identified a number of strong correlations between zonal winds and temperatures near the thermocline. These correlations reflected the strong impacts of eastward propagating ocean Kelvin waves on the heat content of the upper ocean and, thereby, on local air-sea fluxes. One important impact was the creation of favorable or unfavorable conditions for tropical cyclone development. In areas near and east of the dateline, where Kelvin waves could be clearly identified, the development of tropical cyclones seems to have been influenced by the passage of ocean Kelvin waves. Of the 12 tropical cyclones that developed in this area during the study period, 10 formed as the downwelling phase of a Kelvin wave passed the formation area. Since the Kelvin waves in the central Pacific appear to have been forced by tropical cyclones in the western Pacific, these results suggest a possible large scale feedback process in which ocean Kelvin waves are both a response to, and an initiator of, tropical cyclones.

In the second part of this equatorial Pacific air-sea study, we continued our development and application of an equatorial ocean model with embedded mixed layer physics. This model was used to explore the dynamics of the ocean's response to synoptically varying NOGA93 winds during 1991-1992. This modeling effort was conducted in collaboration with Prof. R. Garwood and Ms A. Guest. The model results showed several major variations in the ocean circulation when seasonally varying wind stresses were replaced with synoptically varying ones. These differences

occurred in both small scale, high frequency features and in the large scale, slowly varying flow. In our studies of tropical weather systems, we compared the spectral characteristics of tropical synoptic (5-day) disturbances contained in western Pacific radiosonde observations with the initial analysis and 48 h forecast of the Navy's operational global model during the winter of 1991-1992. The power spectra of the analysis agreed reasonably well with the observations, but the forecast showed larger differences. The westward propagating horizontal structure observed in the v fluctuations was well represented in both the analysis and the forecast, although they tended to produce a higher spatial coherency than that determined from the observations.

The observed vertical structure had a very small low-level tilt in the eastern region and a eastward tilt throughout the troposphere in the western region. This contrasted sharply with the typical summer structure observed previously. This contrast was consistent with the seasonal difference in vertical mean-wind shear. The east-west variation of the vertical structure was reproduced by the analysis, but the forecast structure had a weaker vertical organization over areas where a well-organized structure was observed, and a stronger organization to the west where it was not observed. It appears that the model's dynamics produced a downstream propagation that resulted in an artificial wave structure.

PUBLICATIONS: Gelaro, R., Murphree, T., and Oerens, J., "Rapid Teleconnections Associated with Individual Tropical Cyclones," California Water Resources Bulletin, forthcoming.

Chang, C.-P. and Zambresky, L., "Observed and Navy Operational Global Model Climatologies of Synoptic Disturbances Over the Tropical Western Pacific During Winter 1991-1992," NPS Technical Report NPS-MR-93-003, 1993.

CONFERENCE PRESENTATIONS: Murphree, T., "Satellite Observations of the Evolution and Impacts of the 1991-1993 El Niño," Tenth Annual Pacific Climate Workshop, Pacific Grove, CA, April 1993.

Gelaro, R. and Murphree, T., "Teleconnections Associated with Individual Tropical Cyclones," Tenth Annual Pacific Climate Workshop, Pacific Grove, CA, April 1993.

Murphree, T. and Boothe, M., "Satellite Observations of Synoptic Teleconnections," XVIII General Assembly of the European Geophysical Society, Wiesbaden, Germany, May 1993.

Murphree, T. and Gelaro, R., "Teleconnections Associated With Individual Tropical Cyclones," XVIII General Assembly of the European Geophysical Society, Wiesbaden, Germany, May 1993.

Murphree, T., Gelaro, R., Cooper, G., and Kent, J., "Tropical Cyclone Forcing of the Equatorial Pacific Ocean During the 1991-1992 El Niño," Ninth Conference on Atmospheric and Oceanic Waves and Stability, San Antonio, TX, May 1993.

Murphree, T., Gelaro, R., Neith, M., and Reynolds, C., "Intraseasonal Relationships Between Individual Midlatitude Jets and Global Tropical Heating," Twentieth Conference on Hurricanes and Tropical Meteorology, San Antonio, TX, May 1993.

Gelaro, R., Murphree, T., Goerss, J., and Miller, E., "Rapid Teleconnections Associated with Individual Tropical Cyclones," Twentieth Conference on Hurricanes and Tropical Meteorology, San Antonio, TX, May 1993.

Murphree, T., "Typhoons and Teleconnections," invited seminar, Climate Analysis Center, Washington, DC, June 1993.

Murphree, T., "Synoptic Teleconnections," invited seminar, Climate Analysis Center, Washington, DC, June 1993.

THESES DIRECTED: Swett, W.C., "Spectral Analysis of Synoptic Time Scale Disturbances Over the Tropical Eastern Pacific During Summer 1989, 1990, and 1991," Master's Thesis, March 1993.

Kent, J., "Air-Sea Interaction Patterns in the Equatorial Pacific," Master's Thesis, December 1993.

Weddle, C., "The Effect of Westerly Wind Bursts on a Tropical Ocean General Circulation Model," Master's Thesis, December 1993.

Woll, S., "Short Term Teleconnections Associated With an Individual Tropical Cyclone," Master's Thesis, December 1993.

OTHER: Gelaro, R. and Murphree, T., "Intraseasonal Variations in Tropical - Extratropical Teleconnection Mechanisms," submitted to Journal of the Atmospheric Sciences, July 1993.

Murphree, T., Gelaro, R., Kent, J., and Cooper, G., "Interactions Between Tropical Cyclones and Ocean Kelvin Waves During the 1991-1992 El Niño," to be submitted to the Journal of Geophysical Research, May 1994.

Murphree, T., Gelaro, R., Woll, S., and Goerss, J., "Teleconnections Associated with Individual Tropical Cyclones," to be submitted to Journal of the Atmospheric Sciences, May 1993.

Murphree, T., and Boothe, M., "Satellite Observations of Synoptic Teleconnections, 1991-1993," 30 minute video.

DOD KEY TECHNOLOGY AREA: Environmental Effects, Human-Systems Interfaces.

KEYWORDS: Climate Change, Global Atmosphere, Tropical Ocean, Air-Sea Interaction, Tropical Cyclones, Large-Scale Waves, Jets, Operational Analyses, Prediction Systems.

MESOSCALE AIR-SEA INTERACTION STUDIES

W.A. Nuss Associate Professor

Department of Meteorology

Sponsor and Funding: Office of Naval Research

OBJECTIVES: The primary long-term goal of this ongoing project is to understand how mesoscale sea surface temperature features interact with developing synoptic-scale cyclones. An associated secondary goal is to produce forecast criteria that indicate when strong interaction will occur to aid in forecasting cyclogenesis at sea. The objectives during FY93 were to write a description of the IOP 2 cyclone and prepare three-dimensional analyses for use in numerical model studies.

SUMMARY: During FY93 the mesoscale analyses of the ERICA IOP2 cyclone were used to write a description of the detailed evolution of this cyclone and the associated air-sea interaction. This study has found that the boundary layer and surface interaction during the IOP2 cyclogenesis contributed significantly to the initial cyclogenesis through PBL frontogenesis and continually forced the warm frontal region of the cyclone throughout its life cycle. The pattern of surface heat fluxes prior to cyclogenesis rapidly established a boundary layer front along the north wall of the Gulf Stream. The subsequent initial cyclogenesis occurred in a region where the surface heat flux was a maximum along this front and where convection was possibly being forced by these strong fluxes. Interestingly this pattern of strong heating along the warm front and in the warm sector was found to persist through much of the cyclogenesis. We hypothesize that this heating pattern contributed significantly to the convection along the warm front and

probably was important to the overall development of the cyclone. Three-dimensional analyses were generated using multiquadric interpolation to begin testing the contribution of the surface fluxes to the structure and evolution of the cyclone.

PUBLICATIONS: Bleck, R., Bluestein, L., Bosart, L., Bracken, W. E., Carlson, T., Chapman, J., Dickinson, M., Gyakum, J. R., Hakim, G., Hoffman, J., Kousky, V., Landerian, H., Keyser, D., Lack, G., Nuss, W. A., Roebber, P., Schultz, D., Tyle, K., Sanders, P., and Swack, P., in Proceedings of the Eighth Cyclone Workshop Scientific Summary, Val Morin, Quebec, Canada, 12-14 October 1992, Bulletin of the American Meteorological Society, Vol. 74, No. 7, pp. 1361-1373, July 1993.

OTHER: Two other manuscripts are nearly complete for submission in the near future.

Nuss, W. A. and Goroch, A., "Contribution of Air-sea Interaction to the Genesis of the ERICA IOP 2 Cyclone," in preparation for submission to Monthly Weather Review.

Nuss, W. A., "The Effects of Wind-generated Surface Waves on the Simulation of a Marine Cyclone," in preparation for submission to Monthly Weather Review.

Nuss, W. A., "Three Dimensional Meteorological Analysis using Multi-Quadric Interpolation," to appear in International Journal of Science Computing and Modeling.

Kuo, H.-C. and Huss, W. A., "P-vectors as a Diagnostic Tool for Synoptic-scale Circulations," Submitted to Monthly Weather Review.

DOD KEY TECHNOLOGY AREA:
Environmental Effects.

KEYWORDS: Marine Cyclogenesis, Air-sea interaction, Cyclone forecasting.

COASTAL METEOROLOGICAL STUDIES
W.A. Huss, Associate Professor
Department of Meteorology
Sponsor and Funding: Naval Postgraduate School

OBJECTIVES: The overall objectives of this project are to document the occurrence and evolution of mesoscale coastal meteorological phenomena along the California coast and to examine the performance of synoptic-scale operational numerical forecast models in predicting these phenomena. As part of the examination of the operational model performance, this study aims to identify characteristic synoptic-scale signatures associated with various mesoscale coastal features.

SUMMARY: To document the occurrence and evolution of mesoscale coastal phenomena along the California coast, plans were made to enhance the standard observational network through drifting buoy measurements. During 1993, drifting buoys were identified for this purpose and the purchase of 10 such buoys was initiated. Coastal analysis software has been developed and tested using existing data sources. Preliminary analysis experiments have identified

a multiple pass multiquadric analysis method that can possibly be used to separate the synoptic-scale structure from the mesoscale coastal structure. The multiple pass multiquadric analysis consists of doing a smoothed large-scale analysis which is then subtracted off of an unsmoothed multiquadric analysis to identify mesoscale perturbations.

OTHER: A paper is being prepared for submission covering the analysis of a case study of mesoscale coastal wind effects.

Huss, W. A., "Enhanced Coastal Winds in Advance of a Cold Front Along the California Coast," in preparation for submission to Monthly Weather Review.

DOD KEY TECHNOLOGY AREA:
Environmental Effects.

KEYWORDS: Coastal Meteorology, Coastal Forecasting, Topographic Effects.

REAL-TIME ENVIRONMENTAL INFORMATION NETWORK AND ANALYSIS SYSTEM

W.A. Muss, Associate Professor

P.A. Hirschberg, Research Assistant Professor

C.H. Wash, Professor

Department of Meteorology

Sponsor and Funding: Office of Naval Research

OBJECTIVES: The primary objectives of this project are to develop a demonstration mesoscale atmospheric and oceanic observing network for the Monterey Bay and to assist the University of California, Santa Cruz in developing computer software to manage and display these data. The principle scientific objective of this mesoscale observing network is to study the three-dimensional interaction of the Monterey Bay sea-breeze with the complex topography of the region. A secondary objective of this project is to develop data assimilation and modeling techniques for use in the analysis and visualization of sea-breeze circulations in the Monterey Bay region.

SUMMARY: Considerable progress has been made during 1993 in developing a mesoscale observing network for the Monterey Bay. Arrangements have been made to obtain observations from other local agencies that take meteorological observations. The California Department of Forestry has become a member of the mesoscale observing network by providing data from their 50 plus stations over the entire state. The Monterey Bay Unified Air Pollution Control District has agreed to become members of the network with their stations and arrangements have been made to connect them via INTERNET to NPS. Arrangements have been made with the NOAA Environmental Technology Laboratory to supply three 915 MHz wind profilers, a doppler SODAR, and

monostatic SODARs as needed for an intensive observing period during the summer of 1994. Observing stations of MBARI, UCSC and the Naval Postgraduate School have been either developed or brought into the network. Consulting advice on the display and use of meteorological data has been provided to the University of California, Santa Cruz as needed through meetings with their computer scientists and by sharing our computer programs and data sets with them. The work on the modeling and data assimilation has included obtaining a version of the NRL/VMOC regional atmospheric model, MORAPS, for use in this project. The model has been adapted to run on the NPS Cray computer and plans for the development of the data assimilation have been outlined.

PUBLICATIONS: Mantey, P.A., Garcia-Luna, J.J., Kolsky, H.J., Long, D.D.E., Pang, A.T., Rosen, E.C., Tang, C., Montague, B.R., Abram, M.D., Macy, W.W., Gritton, B.R., Muss, W.A., and Paduan, J., "REINAS: Real-time Environmental Information Network and Analysis System: Phase II Requirements Definition," University of California, Santa Cruz, Computer Research Laboratory Technical Report, 1993.

DOD KEY TECHNOLOGY AREA: Computers, Software, Environmental Effects.

KEYWORDS: Sea-breeze, Visualization, Data Assimilation.

**THE INFLUENCE OF NONUNIFORM DATA DISTRIBUTIONS ON THE RESPONSE OF
THE BARNES OBJECTIVE ANALYSIS SCHEME FOR COASTAL REGIONS**

P.M. Pauley, Research Assistant Professor

R.L. Haney, Chairman & Professor

Department of Meteorology

Sponsor and Funding: Naval Postgraduate School

OBJECTIVE: The goal of the proposed research was to investigate the spectral response behavior of the Barnes objective analysis scheme for random nonuniform data distributions.

SUMMARY: This research is an extension of previous work that examined the spectral response of the Barnes objective analysis scheme for uniform data distributions. In the present research, the uniform (square mesh) data distribution used by Pauley and Wu (1990) was perturbed by adding a normally distributed random displacement to each location. The degree of nonuniformity of the resulting data distribution was controlled by varying the standard deviation (σ) used to generate the normally distributed random numbers. For each σ value used, ten different realizations of random displacements were generated so that results would not be dependent on a given realization.

Once the nonuniform data distributions were determined, a Barnes analysis was performed for each, with the data specified according to a one-dimensional monochromatic sine or cosine wave at a range of wavelengths. A two-dimensional Fourier analysis was then performed on the output from the Barnes analysis to determine the Fourier amplitudes present in the analysis fields at various wavelengths. The ratio of

these Fourier amplitudes to the amplitude of the input wave then defines the response. Responses for the ten realizations for a given degree of nonuniformity (σ) were averaged to yield the mean response.

Results show that the mean spectral response at the input wavelength was similar to the response for the uniform data distribution, with some degradation seen for larger degrees of nonuniformity. The most striking differences were seen in what Pauley and Wu (1990) referred to as the aliasing response. Perturbing the data distribution served to decrease the response at the primary aliased wavelength identified by Pauley and Wu (1990). However, aliasing appeared at a broad range of other wavelengths as the data distribution became more nonuniform. Therefore, errors in the analysis manifested themselves by introducing wavelengths not present in the original data.

OTHER: A manuscript is being prepared for submission to Monthly Weather Review, a refereed journal of the American Meteorological Society.

DOD KEY TECHNOLOGY AREA: Other.

KEYWORDS: Objective Analysis,
Nonuniform Data Distribution,
Spectral Response.

**CASE STUDIES OF THE ABILITY OF THE NAVY MULTIVARIATE OPTIMUM
INTERPOLATION TO DEPICT MESOSCALE PHENOMENA**

P.M. Pauley, Research Assistant Professor

Department of Meteorology

Sponsor and Funding: Naval Research Laboratory-Monterey

OBJECTIVE: The goal of this research was to investigate the ability of the Navy's MVOI analysis system to portray the jet streaks and associated circulations present in the November 1991 "I-5" case.

SUMMARY: This research is part of an ongoing project to investigate the ability of the Navy's MVOI analysis to accurately portray jet streak behavior. The efforts in FY93 were focused on developing and implementing code to compute vertical motion and vertical circulation diagnostics. The latter was proposed by Keyser et al. (1989) to isolate the divergent ageostrophic wind associated with a given vertical motion field and to view the ageostrophic vertical circulation in any arbitrary plane.

The November 1991 "I-5" case was chosen for this work because of the very strong jet streaks located over the Eastern Pacific and Western North America. This case had strong surface winds late in the study period that led to a dust storm in California's San Joaquin Valley and a consequent chain collision on I-5 involving over 100 vehicles. Such a case provides a stringent test of an analysis system for two reasons: first, the jet streaks were located over the data-sparse Eastern Pacific during the early part of the study period and so were not well observed, and second, the jet streaks were so strong that rawinsonde winds were not available in the upper troposphere even when the features had propagated over land. Results showed that significant ageostrophic winds were present at most analysis times,

except 0000Z 30 November. At this time, winds at jet level were weaker and more geostrophic, reflecting the loss of rawinsonde wind observations.

Strong downward motions were present here as well, suggesting the possible influence of a tropopause fold associated with a strong shortwave aloft. Future work will examine analysis fields for the presence of such a structure.

Ongoing work is examining the vertical circulation calculations and constructing vertical cross-sections to further investigate the jet streak structures and the degree to which the analysis has accurately depicted them. Regional model forecasts for this case are also being run at NRL to examine the effect of including ACARS wind observations. Once the model forecasts are available, the vertical motion and vertical circulation diagnostics will be applied to the model datasets to further investigate the influence of the ACARS data on the performance of the analysis.

OTHER: An abstract (coauthored with E. Barker and W. Baker of NRL) has been submitted for the upcoming AMS Numerical Weather Prediction conference, to be held this summer in Portland, OR. Both a conference preprint article and a manuscript for publication in a refereed journal are planned for FY94.

DOD KEY TECHNOLOGY AREA: Environmental effects.

KEYWORDS: Objective Analysis, Jet
Streaks, Ageostrophic Circulations,
Vertical Motion.

IMPROVEMENT OF INITIAL FIELDS OF TROPICAL CYCLONE FORECAST

M.S. Peng, Research Associate Professor

Department of Meteorology

Sponsor and Funding: Naval Research Laboratory

OBJECTIVE: To study the impact of incorporating SSM/I estimated rainfall rate on the tropical cyclone forecast.

SUMMARY: The SSM/I estimated rainfall rates were assimilated in the Naval Research Laboratory limited-area numerical prediction model to improve the initial analysis and prediction of tropical cyclones. Typhoon Flo of 1990, which was observed in Intense Observation Periods (IOP) 5, 6, and 7 of the Tropical Cyclone Motion Experiment-1990 (TCM-90), was chosen for this study. The SSM/I estimated rainfall rates was incorporated into the analysis/prediction by two different assimilation methods. The first method was based on a dynamic initialization in which the prediction model is integrated backward in time adiabatically for 6 h and then forward for 6 h to reach the initial time. During the pre-forecast, diabatic forward integration, the latent heating function in the Kuo cumulus parameterization was replaced by a value that was consistent with the retrieved rainfall rate. The second method was a straight forward in time

assimilation where integration starts 12 h or 24 h prior to the initial time. During the pre-forecast integration the SSM/I rainfall rate was incorporated by a reversed parameterization of the Kuo scheme. In addition, the momentum fields were also relaxed to the initial analysis. For five different forecasts experiments tested for Typhoon Flo, improved intensity and track predictions were resulted when the SSM/I retrieved rainfall rates were assimilated with either of the two methods.

CONFERENCE PRESENTATION: Peng, M. S., "Effect of SSM/I Rainfall Rate on the Tropical Cyclone Forecast," Conference on Weather Analysis and Forecasting, Taipei, Taiwan, 3-5 May 1993.

DOD KEY TECHNOLOGY: Environmental Effects.

KEYWORDS: Rainfall Rates, Forecasts, Tropical Cyclone Motion.

DEVELOPMENT OF THE "INTRODUCTION TO FORECASTING" COURSE

C.H. Wash, Professor

F.R. Williams, Senior Lecture

Department of Meteorology

Sponsor and Funding: Naval Oceanographic Office,
Stennis Space Center, MS

OBJECTIVE: The goal of this project is to revise and update the **FORECASTING FOR THE MID-LATITUDES** course currently used by the Naval Oceanographic Office and Naval Oceanography Command to train enlisted and junior officer forecasters.

SUMMARY: The new course was completed and delivered to the sponsor, the Naval Oceanographic Office. NPS wrote four volumes of forecaster instruction and completed a chart book for student exercises. Four case studies of east coast cyclogenesis over North America and Asia plus a frontal case study for the eastern United States were utilized in the forecast volumes. The course is now being tested by Naval Meteorology and Oceanography Command forecast centers.

PUBLICATIONS: Williams, F.R., Wash, C. H., and Jordan, M.S., "Atmospheric Analysis for Forecasting," Vol. 2 of the Course **INTRODUCTION TO FORECASTING**, METOC 50-1P-0002, Naval Oceanographic Office, p. 148, September 1993.

Wash, C.H., Williams F.R., and Jordan, M.S., "Numerical Weather Prediction and Remote Sensing for Forecasting," Vol. 3 of the Course

INTRODUCTION TO FORECASTING, METOC 50-1P-0002, Naval Oceanographic Office, 126pp, September 1993.

Williams, F.R., Wash, C.H., and Jordan, M.S., "Weather Systems - A Foundation for Forecasting," Volume 4 of the Course **INTRODUCTION TO FORECASTING**, METOC 50-1P-0002, Naval Oceanographic Office, p. 109, September 1993.

Wash, C.H., Williams, F.R., and Jordan, M.S., "Forecast Charts and Forecasting Weather Elements," Volume 5 of the Course **INTRODUCTION TO FORECASTING**, METOC 50-1P-0002, Naval Oceanographic Office, p. 165, September 1993.

Wash, C.H., Williams, F.R., and Jordan, M.S., "Chart Book and Final Exam," Vol. 6 of the Course **INTRODUCTION TO FORECASTING**, METOC 50-1P-0002, Naval Oceanographic Office, p. 95, September 1993.

DOD KEY TECHNOLOGY AREA: Environmental Effects.

KEYWORDS: Weather Forecasting, Meteorological Analysis, Remote Sensing, Extra-tropical Cyclone Fronts, Meteorological Satellites, Numerical Weather Prediction, Doppler, Radar.

REGIONAL SYNOPTIC FORECASTING (PHILIPPINES)

F.R. Williams, Adjunct Professor

Department of Meteorology

Sponsor: Naval Research Laboratory, Monterey

Funding: Naval Postgraduate School and NRL-Monterey

OBJECTIVE: A continuing project to produce handbooks describing the analysis and forecasting of atmospheric and oceanic conditions important to air/sea operations over key areas of interest to the Navy. In particular, the handbooks contain case studies providing newly arriving naval personnel with examples of the accuracy of the Navy Operational Global Atmospheric Prediction System (NOGAPS) in the area. The current handbook covers the Philippine Islands and surrounding waters.

SUMMARY: The analysis and forecasting of atmospheric and oceanic conditions important to air/sea operations in the Philippine Islands area were described. The covered area included the islands - Luzon, the Visayas (the central islands) and Mindanao - from 4.7°N to 21.5°N and from 117°E to 127°E; and the Philippine Sea, Luzon Strait, South China Sea and Sulu Sea. Electromagnetic conditions including standard and anomalous propagation in ducts, plus seasonal climatologies of the southwest and northeast monsoons and tradewind regime were presented. Oceanographic parameters for the four surrounding ocean areas were in-

cluded. Appendices provided additional climatologies, a tropical cyclone characteristic study, climatic normals for 60 Philippine stations, and percent frequencies of wave heights. Five case studies examined the current accuracy of the NOGAPS model analyses and prognoses. Tropical cyclone bulletins issues by the Joint Typhoon Warning Center, Guam, were identified and described; forecast philosophies were discussed. Interaction of Typhoon Yunya and the eruption of Mount Pinatubo volcano in June 1991 was described, and the dangers posed to aviation by volcanic ash were discussed.

PUBLICATIONS: Williams, F.R., Jung, G.H., and Englebreton, R.E., "Forecasters Handbook for the Philippine Islands and Surrounding Waters," Naval Research Laboratory - Monterey, NRL/PU/7541-92-0001, p. 354.

DOD KEY TECHNOLOGY AREA: Environmental Effects.

KEYWORDS: Philippines, Meteorology, Oceanography, Typhoon, Monsoon, Propagation, Ducting.

NUMERICAL MODELING OF TROPICAL CYCLONE STRUCTURE CHANGES

R.T. Williams, Professor

M.S. Peng, Research Associate Professor

Department of Meteorology

Sponsor: Office of Naval Research

Funding: Naval Postgraduate School

OBJECTIVE: To understand the physical processes which control tropical cyclone structure.

SUMMARY: The three-dimensional primitive equation model from the Naval Research Laboratory was adapted to run on the Naval Postgraduate School supercomputer. This model uses a second order finite difference scheme with split-explicit time integration. The model contains full physical parameterization including a modified version of the Kuo scheme for the cumulus convection. The initial experiments were on an f-plane with a spatially uniform environment. A preliminary investigation showed that the dynamics of large-scale tropical cyclones such as super typhoons and monsoon circulations are different from the dynamics of smaller scale cyclones. Dispersion was found to be more important and often a strong anticyclone formed to the southeast of the cyclone. The motion of tropical vortices in east-west mean flows was studied with the barotropic

vorticity equation on the beta-plane. The vortex was embedded in a linear shear flow and in a parabolic jet. With linear shear the vortices moved in the same direction as the no mean flow case when the advection by the mean current was removed. The anti-cyclonic current, however, gave longer trajectories. With the parabolic jet, the Earth's vorticity gradient was more important than the relative vorticity gradient in determining the northward vortex movement.

OTHER: Williams, R.T. and Chan, J.C.-L., "Numerical Studies of the Beta-effect in Tropical Cyclone Motion. Part II: Zonal Mean Flow Effects," will be published in the Journal of the Atmospheric Sciences during 1994.

DOD KEY TECHNOLOGY AREA: Environmental Effects.

KEYWORDS: Tropical Cyclones, Numerical Forecasting.

FRONTAL MODELING

R.T. Williams, Professor

M.S. Peng, Associate Research Professor

Department of Meteorology

Sponsor and Funding: National Science Foundation

OBJECTIVE: Numerical models will be used to understand the dynamics of surface fronts and their relation to density currents.

SUMMARY: (Project began 1 Mar 93) A Boussinesq two-dimensional model was developed to study surface frontogenesis. A sinusoidal, confluent wind field was used to force the frontogenesis. The initial temperature disturbance was confined to the lower part of the domain so that frontogenesis would not occur along the upper boundary. The equations were integrated numerically with second order finite differences and no diffusion terms, with grid increments $\Delta X = 3 \text{ km}$ and $\Delta Z = 0.1 \text{ km}$ the normalized frontal scale collapsed from 550 km to 27 km in 24 hours. Small scale gravity waves were present in the frontal region at the end of the integration.

A variable resolution grid was introduced with the maximum resolution centered on the surface frontal position. With minimum grid sizes of $\Delta X = 500 \text{ m}$ and $\Delta Z = 5 \text{ m}$ the frontal scale reached 2.3 km after 24 hours and the gravity waves had much smaller amplitudes. These results suggest that the inviscid equations would produce a discontinuity if the grid size could be reduced indefinitely. A surface turbulence formulation has been introduced into the model in order to see if fronts can sometimes be converted into density currents as suggested by certain observations.

DOD KEY TECHNOLOGY AREA: Environmental Effects.

KEYWORDS: Front, Frontal Scale.

**DEPARTMENT
OF
METEOROLOGY**

**1993
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and Presentations**

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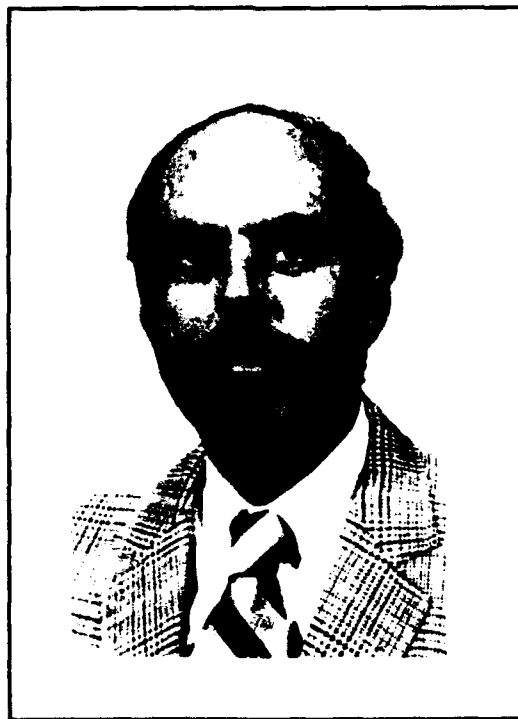
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**DEPARTMENT
OF
NATIONAL SECURITY AFFAIRS**



**Thomas C. Bruneau
Chairman**

DEPARTMENT OF NATIONAL SECURITY AFFAIRS

The research conducted by the faculty in the Department of National Security Affairs expanded in scope and depth during the 1993 Academic Year. More senior faculty were joined by new faculty who were recruited to broaden the teaching and research interests sponsored by the Department. These included in particular the areas of Special Operations and Low Intensity Conflict, Regional Security Policy, and Intelligence Studies. Most of the faculty spent much time outside of Monterey conducting research. These included short trips to Washington, D.C., Norfolk, Honolulu, capital cities in Asia, the Middle East, and Europe, as well as the Chairman's nine month sabbatical leave in Spain and Portugal.

The research themes pursued by the faculty include the following:

- (1) National and Regional Security and Defense Policies including virtually all of Europe, East and West, Russia and Ukraine; Latin America; the Middle East; South, East and South East Asia. The research in these areas deals with such topics as civil/military relations, foreign relations between and among groups of states, the role of regional organizations such as NATO and the UN, and bilateral relations with the United States.
- (2) The general topics of revolutions, low intensity conflict, and special operations. While dealing with the overall theme of political violence and insurrections, and covering much of the world, the strongest focus has been on different cases in Latin America.
- (3) U.S. defense policy, particularly regarding the role of different national institutions including the Executive and Legislative branches and the different services.
- (4) The overall theme of intelligence, and how it is becoming increasingly joint. Here the emphasis is primarily on the emerging themes of intelligence and the new or changing structures whereby the United States obtains and processes information.
- (5) U.S. Naval strategy, and particularly the implications for the Navy of the new doctrine in "From the Sea." The focus on new naval strategy holds implications for the relationships with other services and allied services.
- (6) The economics of U.S. and other countries' defense strategies. Here the emphasis is on the costs of defense, the economic implications of defense, and such themes as "economic warfare."
- (7) Certain "hot" topics of tremendous importance including counter-proliferation, cyberwar, peacekeeping, deterrence, and arms control. In many cases these topics are situated in a national or regional context, and they often bridge several of the themes noted in the other categories.

The faculty in the Department have developed a research agenda which encompasses the most important and relevant themes of international security and defense. They are virtually all active researchers with great experience in their areas

of topics of choice and with an emphasis upon analysis and policy. The research is increasingly supported by reimbursable funding. The results of the research is provided to sponsors through reports and briefings, and is often made available to a larger public through the publication of scholarly articles and books.

GERMAN UNITY AND PROFESSIONALISM IN GERMAN OFFICER CORPS

**D. Abenheim, Associate Professor
Department of National Security Affairs
Sponsor and Funding: Director of Net Assessment,
Office of Secretary of Defense**

OBJECTIVE: The present research has sought to assess the impact of the collapse of a Communist military on officer professionalism and examine the efforts of the western Germans to absorb former communists into ranks of a NATO military. Also key to provide insights as to officer professionalism in other USSR style armies and navies.

SUMMARY: The sudden end of the GDR in 1989/90 created the extraordinary situation of one Army/Navy/Air Force absorbing most of the officers of a former opponent organizes along the lines of the armed forces of the USSR. Chief among the problems has been the role of political indoctrination in the concept of command and the social welfare of the officers affected. While western ideas of civil-military relations came as foreign to many GDR officers, the several thousand who have adapted to new conditions seem confident of their future once questions of social welfare have been resolved. Explicit communist indoctrination led to a widely different ideal of command.

Nonetheless, the western Germans have made important strides and learned lessons applicable to future experience in the expansion of NATO.

PUBLICATION: Abenheim, D., "German Unity and the Soldier: Problems of Command and Personnel," NPS Technical Report, NPS-NS-93-009, March 1993.

CONFERENCE PRESENTATION: Abenheim, D., "German Soldier and German Unity," Center for International Security and Arms Control, Stanford, CA, 17 January 1993.

OTHER: The investigator is preparing a book-length monograph publication with Princeton University, press on the results of this project. Completion is expected in late 1995.

DOD KEY TECHNOLOGY AREA: Other.

KEYWORDS: Communist Military, Western Germans.

FUTURE OF TRANSATLANTIC SECURITY

**J.S. Breemer, Assistant Professor
Department of National Security Affairs
Sponsor and Funding: Naval Postgraduate School**

OBJECTIVE: The objective of this 3 year project was to investigate and report on the implications of the demise of the Soviet Union and the Warsaw Pact for the U.S.-European security partnership.

SUMMARY: The principal investigator, in close coordination with the project sponsor, N-513, developed an agenda of policy issue areas that have been central to the transatlantic security "debate" since the collapse of the Berlin Wall. Identified issues were reviewed and analyzed with a particular eye on NATO-European perspectives. This effect entailed a series of extensive discussions and interviews with key NATO-European foreign and military policy decision-makers, as well as academic policy analysts. Key issue areas covered included: (1) NATO-European views on naval arms control and confidence-building measures, (2) U.S. vice European perspectives on "reconstitution;" (3) European perspectives on the future of multi-national naval cooperation, and (4) prospects for a European defense identity.

PUBLICATION: Breemer, J.S., "U.S. Forces in Europe: The Search for a Mission," in Tritten and Stockton, Eds, Reconstituting America's Defense: The New U.S. National Security Strategy, New York: Praeger, pp. 137-152, 1992.

CONFERENCE PRESENTATIONS: Breemer, J.S., "The New Navy," Annual Meeting of the International Security Studies Section of the International Studies Association - West, Phoenix, AZ, November 1992.

Breemer, J.S., "From the Sea: Implications for the U.S. Navy and European Security," Royal Naval College, Greenwich, UK and the Netherlands Armed Forces Staff College, The Hague, The Netherlands, January 1993.

DOD KEY TECHNOLOGY AREA: Other.

KEYWORDS: Naval Strategy, Regional Security, Arms Control Europe.

**THE UNITED STATES AND IBERIA AFTER THE COLD WAR
CHALLENGES AND OPPORTUNITIES IN THE NEW SECURITY ENVIRONMENT**

T.C. Bruneau, Chairman and Professor

Department of National Security Affairs

Sponsor and Funding: Faculty Development from the

Naval Postgraduate School and the Office of the

Assistant Secretary of Defense for Policy (IPS)

OBJECTIVE: To analyze the present and likely relationships between the Iberian democracies of Portugal and Spain with the United States in the several broad areas of defense.

SUMMARY: The relationships between the United States and the two Iberian countries of Portugal and Spain have changed very substantially during the past decade. This was due initially to the results of the democratization of the two countries and later to the implications of the end of the Cold War. In order to analyze the overall relationship a number of key areas were studied. These included the following: strategic thinking in the civilian and military contexts; relationships with NATO; relationships with the emerging European Security and Defense Identity; perception of threats; and the overall bilateral relationship with the United States. The research was conducted in Portugal and Spain between October 1992 and June 1993, and involved extensive interviews with military and civilian experts and officials.

PUBLICATIONS: Bruneau, T. C., "Portugal," Encyclopedia of Democracy, forthcoming 1994.

Bruneau, T. C., "Collaborator in Arend Lijphart," Electoral Systems and Party Systems: A Study of Twenty-Seven Democracies 1945-1990, New York: Oxford University Press, forthcoming 1994.

Bruneau, T. C., "The Role of the Provisional Governments in the Transition to Democracy," in Juan Linz and Yossi Shain, eds., Interim Governments and Democratic Transitions, New York: Cambridge University Press, forthcoming 1994.

CONFERENCE PRESENTATIONS: Bruneau, T. C., "Portuguese Defense Policies," at a seminar hosted at the Centro Espanol de Relaciones Internacionales, Madrid, 25 May 1993.

Bruneau, T. C., "U.S.-Portuguese Defense Relations," at a seminar hosted by the Instituto de Estudos Estrategicos e Internacionais, Lisbon, scheduled 1 June 1994.

OTHER: A set of five reports were provided to research sponsors in September 1993. These included the following offices: OASD/RSA (EUR POL); OUJD (p) S & R Policy Research; N 31/52; and N 524. In addition, the investigator used the data obtained in the project to help brief the Ambassador Designate to Spain, Dr. Richard Gardner, at the Foreign Service Institute, Arlington, VA, on 8 September 1993. The investigator is working with the data to prepare papers to submit to academic journals.

DOD KEY TECHNOLOGY AREA: Other.

KEYWORDS: Cold War, Democracy, Spain, Portugal.

OPERATIONAL INTELLIGENCE IN JOINT WARFARE

R.N. Channell, Adjunct Professor

Department of National Security Affairs

Sponsor: Director of Intelligence, The Joint Staff

Funding: Naval Postgraduate School

OBJECTIVE: To develop an understanding of the structure and logic of joint operational intelligence (opintel) support to the operating forces, with emphasis on the CINC and the JTF; to identify the issues and problem areas, and to provide analysis, comment, and recommendations to the joint intelligence structure for consideration; to improve the ability of NPS to provide meaningful instruction regarding the current status of joint opintel, and to provide a framework within which intelligence students can explore thesis material and contribute to joint opintel issues; and to install, study, and comment on the emerging new intelligence interface for joint opintel, the Joint Deployable Intelligence Support System (JDISS).

SUMMARY: Major changes have occurred in the way that operational intelligence (opintel) is provided to the operating forces. The new Joint Intelligence Centers have assumed most functions for operational intelligence, but the services still provide a degree of support. The opintel connectivity among the operating forces, the service organizations, the JIC's, and the national level assets has not been fully resolved, with the solutions not consistent among the CINC's. This presents problems to forces that may deploy to any CINC AOR. Other issues include the balance between current intelligence and database support; the proper mix between JIC and service unique support; the necessity to continue required opintel support to deployed naval

forces; and the need for area and other educational expertise.

The research to be accomplished was originally estimated to include: a visit to Washington, DC, to identify the NMJIC structure and to determine the interface of the other intelligence agencies with the new structure; a visit to the new JIC's at STRATCOM and CENTCOM to obtain the latest structure and identify the issues; a revisit to CINCPAC and JICPAC, as the material at hand was dated, and the issue of forward support to deployed forces had not been resolved; a visit to the new JAC for EUCOM and at EUCOM regarding service element support and the interface with NATO, WEU, and UN peacekeepers in the Balkans. Installation of the JDISS was to be an integral part of the project, essential to drawing current data, imagery, and directives from the new joint opintel system.

The P.I. traveled extensively during the late summer and fall of 1993 to meet the above listed requirements. Specifically, visits were made to JCS J2/NMJIC, ONI, ACOM J2/AIC, STRATCOM J2/JIC, CENTCOM J2/JIC, PACOM J2/JICPAC, as well as CNO, CINCLANTFLT, CINCPACFLT, COMTHIRDFLT and selected Carrier Battle Group N2's. The P.I. was not able to visit EUCOM and the new JAC because sufficient travel funds were not available. Although progress has been made on the JDISS, unfortunately, sufficient funds have not been made available to obtain the equipment.

A report on joint operational intelligence is in preparation to be provided to the sponsor and other J2's, and will be used as a text for instruction in the Joint Intelligence Curriculum, and for Strategy/JPME as needed. Student theses have already been produced relating to this project, and it is anticipated that such theses will continue, as well as student visits to various intelligence analysis centers.

This project relates directly to intelligence courses in the NSA department, and has already made major contributions to these courses. It is anticipated that further contributions will be made to the teaching of strategic planning and to JPME here at NPS. The project also relates directly to joint operations, and to naval and other U.S. operating forces, and is currently a key issue in the warfighting arena.

CONFERENCE PRESENTATIONS: Informal presentations at various J2's and N2's.

THESES DIRECTED: Sheehan, F.X., LT, USN, Battle Group Intelligence Support to Theater Level Battle Damage Assessment (U), Master's Thesis, June 1993.

Lindsay, R.R., "A Critical Appraisal of Target Development," Master's Thesis, June 1993.

Button, D.J., MAJ, USMC, (second reader), "Marine Corps Intelligence and All-Source Fused Analysis...", Master's Thesis, June 1993.

Hopkins, T.H., LCDR, USN, "Intelligence Support to Special Warfare in Korea (U)," Master's Thesis, September 1993.

Currently, two theses on intelligence issues regarding the Global Positioning System, and mobile commercial telephones.

OTHER: Preliminary reports prepared following visits to JCS J2, STRATCOM, CENTCOM, and PACOM.

"Joint Operational Intelligence: The New Look," in preparation.

DOD KEY TECHNOLOGY AREA: Communications Networking, Human System Interfaces, Software, and Computers (emphasis on C4 and I aspects).

KEYWORDS: Joint Operational Intelligence, Joint Intelligence Interface, JDISS, Joint Intelligence Centers, Joint Task Force Support, Fusion/Filtering.

**WEAPONS PROLIFERATION IN THE DEVELOPING WORLD: THE ROLE OF
"STATUS" AND "PRESTIGE" PROCESSES**

D.P. Eyre, Lecturer

Department of National Security Affairs

**Sponsor and Funding: U.S. Air Force Institute for
National Security Affairs**

OBJECTIVE: The goal of this project was to improve the formulation of arguments about the role of status and prestige in weapons proliferation, and to conduct preliminary empirical evaluation of these arguments. This work is part of an ongoing project.

SUMMARY: Theoretical arguments for the project were drawn from earlier work by the primary investigator (Mark C. Suchman and Dana P. Eyre, 1992, "Military Procurement as Rational Myth: Notes on the Social Construction of Weapons Proliferation," Sociological Forum, Vol. 7, No. 1). Data (primarily weapon systems inventories, by country, by year, and dates of first acquisition of major weapons systems) necessary for the empirical evaluation of these arguments were gathered from open source materials. A series of quantitative analyses examining patterns of proliferation in the developing world were conducted in order to evaluate the arguments offered. In the first phase of the project cross-sectional

regressions of country weapons inventories, in a panel design, for the period 1970-1981 were conducted. Preliminary results from this exploratory work suggested both strong support for the arguments under evaluation and suggested useful modifications to the arguments and the research design. In the second stage of the work, currently in progress, I will use event history analysis for the analysis of patterns of weapons proliferation. Coding of data has been partially completed (panels for 1970, 1975, and 1980, for a sample states) and continues.

CONFERENCE PRESENTATION: Eyre, D.P., "Cross National Trends in Weapons Proliferation and Military Knowledge," Social Science History Association Annual Meeting, MD, November 1993.

DOD KEY TECHNOLOGY AREA: Other.

KEYWORDS: Weapons Proliferation, Arms Transfer Status.

**LEARNING TO LIVE WITH THE BOMB: THE POLITICS OF
NUCLEAR PROLIFERATION IN SOUTH ASIA**

P.R. Lavoy, Assistant Professor

Department of National Security Affairs

Sponsor and Funding: Naval Postgraduate School

OBJECTIVE: The objective of this two-year project is to examine and report on the evolution of nuclear weapons activities in India and Pakistan.

SUMMARY: The principal investigator is conducting an extensive research project on many dimensions of the nuclear proliferation problem in South Asia. The specific aims of this research are: (1) to explain the conditions that motivate India and Pakistan to develop and expand their nuclear weapons capabilities; (2) to examine U.S. and other foreign efforts to influence Indian and Pakistani nuclear decision making; (3) to understand the military and political problems posed by nuclear weapons in South Asia; and (4) to explore arms control and confidence-building solutions for these problems.

PUBLICATIONS: Lavoy, P.R., "Nuclear Myths and the Causes of Nuclear Proliferation," Security Studies, Vol. 2, Nos. 3/4, Spring/Summer '993.

CONFERENCE PRESENTATIONS: Lavoy, P.R., "Missile Proliferation in South Asia," (comment on paper written by Dr. Brahma Chellaney) at Joint Indo-U.S. Conference on Nonproliferation and Technology Transfer, University of Pennsylvania, November 1993.

DOD KEY TECHNOLOGY AREA: Other.

KEYWORDS: Nuclear Weapons, Nuclear Proliferation, India, Pakistan.

IRAN AND ITS NEIGHBORS: IMPLICATIONS FOR THE UNITED STATES

R.H. Magnus, Associate Professor

Department of National Security Affairs

**Sponsor and Funding: Naval Security Support Group Activity,
Washington, DC**

OBJECTIVE: This study investigates the foreign policies of the Islamic Republic of Iran from the point of view of the major neighboring countries of Turkey, Pakistan, the Gulf States and Afghanistan. These states have a long history and a great current policy interest in the policies and behavior of Iran. Their views are both directly and indirectly. Directly, they affect regional friends and allies of the United States. Indirectly, they provide insights into Iranian policies relevant to the United States in general.

SUMMARY: A final report of twenty-five pages, Iran and Its Neighbors, was submitted to the sponsor in April. An additional briefing was made to the sponsor, and agreement was reached for further research to develop this topic in 1993-94. This report was also submitted to the Navy Staff, Pol/Mil and briefed to RADM Doran. It was briefed to staff of

the OASD/ISA, with participants from JCS in attendance. It was also submitted and briefed to Ms. Anne Davis Alexander, Regional Analyst, Near East and South Asia, National Security Council Staff.

PUBLICATION: Magnus, R. H., "Interview with Afghan Foreign Minister," Afghanistan Forum, Vol. XXI, No. 6, pp. 34-35, 1993.

THESIS DIRECTED: Woodyard, Bruce L., LCDR, USN, "Revolution or Realism?: United States-Iranian Relations in Post-Cold War Era," Master's Thesis, September 1993.

OTHER: The author is working to develop this in the form of an article.

DOD KEY TECHNOLOGY AREA: Other.

KEYWORDS: Iran, Middle East, South Asia, Turkey.

DOMESTIC SOURCES OF IRANIAN SECURITY POLICY

R.H. Magnus, Associate Professor

Department of National Security Affairs

Sponsor and Funding: Naval Security Support Group Activity

OBJECTIVE: This project aims at the identification and explanation of the internal sources of Iranian security policy through the examination of the respective contributions of ideology, rational strategic and national interest, rival domestic interest groups in the political system and the clash of interests between different bureaucratic institutions in policy and decision-making process. A monitoring of the evaluations of Iranian policies by regional neighbors will continue from the previous research project, "Iran and Its Neighbors."

SUMMARY: Three research trips were taken in the Fall Quarter 1993:

(1) Washington, D.C.: Interviews with foreign and U.S. scholars, interview with the Afghan Foreign Minister and with the Political Counselor of the

Embassy of Uzbekistan, interview with Acquisitions Director, Library of Congress.

(2) New York City: Interviews with Afghan Ambassador to the United Nations, Liaison Officer of the Iranian Mission to the United Nations, interviews with U.S. scholars.

(3) Research Triangle, N.C.: Participation in Annual Middle East Studies Meeting.

CONFERENCE PRESENTATION: None in reporting period. One scheduled for 1994 Middle East Studies Association Meeting, Phoenix, AZ, November 1994.

DOD KEY TECHNOLOGY AREA: Other.

KEYWORDS: Iran, Middle East, South Asia, Central Asia, Turkey.

**BRAZIL'S NATIONAL SECURITY STRATEGY: IMPLICATIONS FOR
HEMISPHERIC SECURITY**

S.D. Tollefson, Assistant Professor
Department of National Security Affairs

Sponsor and Funding: U.S. Navy; Office of the Secretary of
Defense, Regional Security Affairs, Inter-American Region

OBJECTIVE: The goal of this three-year project is to investigate Brazil's national security strategy (development, security and foreign policies) and the implications of that strategy for Brazilian, Latin American and U.S. security.

SUMMARY: The research examined key issues in Brazil's national security strategy, including the nuclear programs; arms industry and weapons transfers; ballistic missile programs; border projects; and narco-trafficking. The research included extensive travel to Latin America and Washington, D.C. The research was comparative in nature, and also examined national security issues related to Argentina and Chile.

PUBLICATIONS: Tollefson, S. D., "Brazil: National Security," chapter 5 in Brazil: a Country Study, (Area Handbook Series), U.S. Government Printing Office, forthcoming.

Tollefson, S. D. and English, A. J., "Chile National Security," chapter 5 in Chile: A Country Study, (Area Handbook Series), U.S. Government Printing Office, forthcoming 1994.

Tollefson, S. D., "El Condor Pasa: The Demise of Argentina's Ballistic Missile Program," Chapter 11 in William C. Potter and Harlan W. Jencks, eds., The International Missile Bazaar: The New Suppliers' Network, pp. 255-277, Boulder, CO, Westview Press, forthcoming 1994.

Tollefson, S. D., "Brazil: International Relations," in Handbook

of Latin American Studies/Social Sciences, No. 51, Austin: University of Texas Press, forthcoming 1994.

Tollefson, S. D., "Argentina: National Security," Chapter 5 in Argentina: A Country Study, (Area Handbook Series), U.S. Government Printing Office, forthcoming, to be published 1995.

CONFERENCE PRESENTATIONS: Tollefson, S. D., (invited), "From Collor to Itamar Franco: U.S.-Brazilian Security Relations and their Implications for Civil-Military Dynamics in Brazil," 14th Annual Meeting of the Middle Atlantic Council of Latin American Studies, Penn State University, University Park, PA, 3 April 1993.

Tollefson, S. D., "Argentina and the Missile Technology Control Regime: A Reassessment," 34th Annual Convention of the International Studies Association, Acapulco, Mexico, 25 March 1993.

Tollefson, S. D., (chaired and served as discussant on panel), "Changing Security Policies in a Changing World Order: Implications for Latin America," 34th Annual Convention of the ISA, Acapulco, Mexico, 25 March 1993.

THESES DIRECTED: Lundgren, Kenneth S., CAPT, USA, "Brazil's National Defense Strategy: Prospects for the Twenty-First Century," Master's Thesis, June 1993, main advisor. Second reader, Dana Byre.

Ryan, Michael B., LT, USN, "Calha Norte: Explaining Brazilian Army Presence in the Amazon," Master's Thesis, June 1993, main advisor. Second reader, Dana Eyre.

DOD KEY TECHNOLOGY AREA: Other.

KEYWORDS: Brazil, Nuclear, Missile, Security, Amazon.

OTHER: PI was visiting researcher at the Facultad Latinoamericana de Ciencias Sociales (FLACSO), Santiago, Chile, August 1993-April 1994. While in Chile, PI traveled extensively to Brazil, Argentina, Paraguay, and Uruguay.

POST SOVIET SECURITY ENVIRONMENT

M. Tsypkin, Associate Professor

R.N. Channell, Lecturer

Department of National Security Affairs

Sponsor and Funding: Naval Security Group Support Activity

OBJECTIVE: This is a multiyear project designed to determine long-term trends in the security environment in the post-Soviet states. This year the project has concentrated on formulation and execution of military policies of major post-Soviet states, such as Russia and Ukraine, as well as on the military policies of states involved in small- and medium scale regional conflicts (Georgia, Armenia, Azerbaijan). I wanted to establish the relationship between declaratory posture and actual future military policies of Russia, the possible impact of Ukrainian general purpose forces on Russian military posture, and the relationship between the conflicts Transcaucasia and Central Asia and Russian military policy.

SUMMARY: There is no inflexible relationship between declared military doctrine and actual military posture of Russia, due to multiplicity of decision-making inputs, fluid political situation, and unresolved problems of the defense industry. While Russian military doctrine emphasizes the development of mobile power-projection forces, there is no clear blueprint for action in this direction, although efforts would likely be made to increase the power projection capability of the Russian military forces to act along Russia's periphery. The wars in Transcaucasia and Central Asia are strengthening this tendency. So does the relative military weakness of the former Soviet republics, none of which has

substantial general purpose forces. The conclusion is that Russia's military will remain centered around ground forces and tank-heavy, but will nevertheless develop enough power-projection capability to exercise decisive influence along its periphery.

These ideas were extensively debated during a conference Post-Soviet Military Policies: Russia, Ukraine and others, held at NPS in November 1993. Conference participants included respected Russian and American specialists. The sponsor sent its representative to the conference.

PUBLICATION: Tsypkin, M., "Post-Soviet Military Policies: Russia, Ukraine and Others," NPS Technical Report, forthcoming, (conference proceedings, including transcribed debates).

THESIS DIRECTED: Hove, Richard A. and Tersch, Eric J., "COCOM and the Future of Conventional Arms Exports in the Former Communist Bloc," Master's Thesis, December 1993.

OTHER: The PI is preparing an edited book on the basis of the proceedings of the conference on Post-Soviet Military Policies: Russia, Ukraine and Others. Informal briefings for officials at OSD and CNO.

DOD KEY TECHNOLOGY AREA: Other.

KEYWORDS: Russia, Military.

ARMS CONTROL COMPLIANCE: FUTURE ISSUES

J.J. Wirtz, Assistant Professor

Department of National Security Affairs

**Sponsor and Funding: Office of the Assistant Secretary of
the Navy (Research and Acquisitions)**

OBJECTIVE: The purpose of this project is to provide support to the Office of the Assistant Secretary of the Navy by responding to a series of research questions related to arms control compliance.

SUMMARY: This project will respond to a series of research questions posed by the Office of the Secretary of the Navy concerning future issues related to arms control compliance. The project itself actually represents several research initiatives, conducted by faculty, students, and research assistants, under the supervisions of the PI. In addition to these specified projects, however, it is expected that the research initiative will evolve continuously to better support the office of the Assistant Secretary of the Navy. At the moment, four major research initiatives are planned for this project.

PUBLICATION: Wirtz, J. J., "The Future of Arms Control," in progress.

OTHER: Carr, R., CDR, USN, "A Nuclear Waste Treaty? Implications for the U.S. Navy," article submitted for publication.

THESES DIRECTED: Green, Daniel, LT, USN, "Open Source Monitoring of Threat Technologies," Master of Arts, 16 December 1993.

Blackburn, Douglas, "The Chemical Weapons Convention Verification Regime: A Model for a New NPT?" Master of Arts, 16 December 1993.

DOD KEY TECHNOLOGY AREA: Other.

KEYWORDS: Arms Control.

STRUCTURAL FACTORS IN THE LONG-TERM COMPETITION

D.S. Yost, Professor

Department of National Security Affairs

**Sponsor and Funding: Under Secretary of Defense for Policy
and Director of Net Assessment,
Office of the Secretary of Defense**

OBJECTIVE: When the research began in 1986, the research monitor, the Director of Net Assessment in the Office of the Secretary of Defense, directed that the research effort focus on the analysis of security issues relating to Europe.

SUMMARY: The research involved analysis of primary sources dealing with European security problems, including West European views on topics such as the Conference on Security and Cooperation in Europe and possible Western responses to potential crises in Eastern Europe and the former Soviet Union. Special attention was devoted to France, Britain, and Germany, especially with respect to the future of NATO and nuclear deterrence in Europe as well as West European security cooperation.

PUBLICATIONS: Yost, D.S., "France [and Arms Control]," in Fen Hampson, Harald von Riekhoff and John Roper, Eds., The Allies and Arms Control, Baltimore: Johns Hopkins University Press, pp. 162-188, 1992.

Yost, D.S., Les États-Unis et la sécurité européenne, (Paris: Centre d'Étude des Relations entre Technologies et Stratégies (CREST), Ecole Polytechnique, p. 77, 1992.

Yost, D.S., Western Europe and Nuclear Weapons, CSTS-41-93 (Livermore, Calif: Center for Security and Technology Studies, Lawrence Livermore National Laboratory, p. 27, 1993.

CONFERENCE PRESENTATIONS: Yost, D.S., "Nuclear Weapons Issues in Europe," at the Managing Nuclear Weapons in a Changing World Conference at Lawrence Livermore National Laboratory, Livermore, CA, 17 November 1992.

Yost, D.S., "Nuclear Weapons Issues in France," at the conference on Future French, Chinese, and British Nuclear Weapons Policies, sponsored by the Institute on Global Conflict and Cooperation, University of California, San Diego, 2-3 June 1993.

THESES DIRECTED: Fuller, D.G., LT, USN, "NATO's Out-of-Area Disputes: Prospects for Common Western Strategies in the Middle East," Master's Thesis, December 1992.

Dixon, T.A., 1LT, USAF, "Nuclear Proliferation: Lessons Learned from the Iraqi Case," Master's Thesis, December 1992.

Gunning, E.G., Jr., LT, USN, "Germany and the Future of Nuclear Deterrence in Europe," Master's Thesis, December 1992.

Heron, C.M., LCDR, USN, "Probable Trends in Terrorism in Western Europe," Master's Thesis, December 1992.

Cochran, P.M., LT, USAF, "U.S. Interests in European Security Following the Cold War," Master's Thesis, December 1992.

Gilpin, K., LT, USN, "The United States, the United Nations, and the

Legitimation of the Use of Force,"
Master's Thesis, June 1993.

Becker, M.D., LT, USN, "Strategic
Culture and Ballistic Missile
Defense: Russia and the United
States," Master's Thesis, June 1993.

DOD KEY TECHNOLOGY AREA: Other.

KEYWORDS: NATO, Europe, Strategy,
Nuclear Deterrence.

ANALYTICAL TRENDS REGARDING THE MILITARY-TECHNICAL REVOLUTION

D.S. Yost, Professor

Department of National Security Affairs

Sponsor and Funding: Under Secretary of Defense for Acquisition
and Technology and Director of Net Assessment,
Office of the Secretary of Defense

OBJECTIVE: The objective is to
advance understanding of French and
European security policy
developments, especially regarding
the strategic implications of the
military-technical revolution.

SUMMARY: The research has involved
analysis of primary sources dealing
with French and European analyses of
how new technologies may be combined
with innovative operational concepts
and organizational adaptations to
fundamentally change the character
and conduct of military operations.
The key new technologies include
information systems to gather,
process, and disseminate data;
extended-range, advanced conventional
munitions; and simulations techniques
to prepare and train forces and to
develop new types of capabilities and

operational concepts.

PUBLICATIONS: Yost, D.S., "France
and the Gulf War of 1990-1991:
Political-Military Lessons Learned,"
Journal of Strategic Studies, Vol.
16, pp. 339-374, September 1993.

Yost, D.S., "The Defense Policy of
France," in Douglas J. Murray and
Paul R. Viotti, Eds., The Defense
Policies of Nations: A Comparative
Study, third edition, Baltimore:
Johns Hopkins University Press,
forthcoming 1994.

DOD KEY TECHNOLOGY AREA: Other.

KEYWORDS: Military-Technical
Revolution, Strategy, NATO, Europe,
France.

EUROPE IN THE NEW POLITICAL-MILITARY ENVIRONMENT

D.S. Yost, Professor

Department of National Security Affairs

Sponsor and Funding: Naval Security Group Support Activity

OBJECTIVE: The objective is to advance understanding of West European, and notably French, assessments of the new international political-military environment.

SUMMARY: The research effort has emphasized the analysis of primary sources regarding international security issues, including West European views on topics such as the military-technical revolution and possible Western responses to potential crises in Eastern Europe and the former Soviet Union. Special attention has been devoted to France, Britain, and Germany, especially with

respect to military-technical innovation, nuclear deterrence, the proliferation of weapons of mass destruction, and technology transfer controls.

PUBLICATION: Yost, D.S., "Europe and Nuclear Deterrence," Survival, Vol. 35, pp. 97-120, Autumn 1993.

DOD KEY TECHNOLOGY AREA: Other.

KEYWORDS: Military-Technical Revolution, Proliferation, Europe, France, Technology Transfers, Nuclear Deterrence.

**DEPARTMENT
OF
NATIONAL SECURITY AFFAIRS**

**1993
Faculty Publications
and Presentations**

JOURNAL ARTICLES

Abenheim, D., "The Search for Military Tradition in German Unity," German Politics and Society, Issue 130, pp. 61-74, Fall 1993.

Arquilla, J. and Ronfeldt, D., "Cyberwar is Coming!" Comparative Strategy, Vol. 12, pp. 141-165, Fall 1993.

Breemer, J.S., "Where are the Submarines? Deterrence, Naval Presence, and the Submarine Fleet," U.S. Naval Institute, January 1993.

Breemer, J.S., "The Future of the Submarine: Looking for a Mission or Adapting to Change?" Maritime Patrol Aviation, March 1993.

Breemer, J.S., "Onderzeeboten voor Crisismanagement," Marineblad, The Hague, The Netherlands, June 1993.

Breemer, J.S., "Naval Strategy is Dead," U.S. Naval Institute, February 1993.

Lavoy, P.R., "Nuclear Myths and the Causes of Nuclear Proliferation," Security Studies, Vol. 2, Nos. 3/4, Spring/Summer 1993.

Looney, R.E., "Foreign Workers and the Provision of Public Services: The Case of Kuwait," International Journal of Social Economics, Vol. 20, No. 1, pp. 24-39, 1993.

Looney, R.E., "Government Expenditures and Third World Economic Growth in the 1980s: The Impact of Defense Expenditures," Canadian Journal of Development Studies, Vol. XIV, No. 1, pp. 23-42, 1993.

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**DEPARTMENT
OF
OCEANOGRAPHY**



**Curtis A. Collins
Chairman**

DEPARTMENT OF OCEANOGRAPHY

The Oceanography Department has developed a broad research program focused on physical oceanography to meet the anticipated future needs of the Navy. Our priority basic research themes are the development of scientific capabilities to measure, analyze and forecast fields of littoral ocean variables which occur in association with synoptic/mesoscale processes over limited regional and temporal domains. The areas of emphasis include coastal and nearshore ocean dynamics, air-sea interaction phenomena and boundary currents. Regions of interest include the marginal sea ice zone, coastal ocean regions and strategic straits of the world.

Our priority applied research themes are the application of analyses and forecasts of upper ocean synoptic/mesoscale variability to Naval operations. Areas of emphasis include the impact of littoral processes, eddies and boundary currents on ocean surveillance systems, the effect of coastal ocean response storms on acoustic propagations and ambient noise and the impact that nearshore processes exert on the wave climate and beach character.

These research themes require the development of numerical ocean prediction and synoptic oceanography capabilities. They are achieved through employment of modern dynamical and mathematical principles, numerical and statistical methods, computational and graphical facilities, and in-situ and remote sensing observation.

The diverse talents of the faculty of the department are blended by the use of these various techniques to solve problems of common interest. Monterey Bay is a convenient laboratory for studying littoral processes. Our students are actively involved in these research programs and participate in research cruises, conference presentations and as co-authors of research reports and papers. Much of our research results, both theoretical and applied, are incorporated into the curricula we support. A summarization of particular research areas follows below.

COASTAL AND NEARSHORE OCEANOGRAPHY

Professors C.A. Collins, N. Garfield and Professor Carter began regular RAFOS float measurements of the California Undercurrent. The sponsor for these studies is ONR. Professors S.R. Ramp, Collins, Garfield and L. Rosenfeld continued analysis of hydrographic and current meter data in the region to the west of the Farallons. These studies were sponsored by the EPA and the Western Division, Naval Engineering Facilities Command. Professor S.R. Ramp and C.A. Collins continued time series measurements of the current and water mass properties over the continental slope off Pt. Sur to study the long-term seasonal and interannual variability of the flow. Prof. Ramp is also investigating the mesoscale variability of weakly nonlinear systems, a five year ONR accelerated research initiative, to study the energy exchanges occurring in eastern boundary currents.

Under sponsorship of ONR, Professor M.L. Batteen is utilizing climatological data bases for wind and thermal forcing in an eddy-resolving, primitive equation model to study the generation of currents and eddies in the California Current System.

Professors R.H. Bourke and M. Garfield have expanded the IDEA satellite imagery library by acquiring SSM/I passive microwave data for the Arctic Ocean. These data were used to support studies of large ice floe automated tracking and frontal dynamics in the Barents Sea. The project is sponsored by the Naval Polar Oceanography Center and NPS.

Professor J. D. Paduan, with funding from ONR, is using satellite-tracked surface drifters to map the large-scale horizontal surface convergence and eddy statistics in the northeast Atlantic Ocean. He is conducting intensive, single-eddy surveys of two features in the California Current System. With support from NPS he is undertaking studies of coastal circulation problems in Monterey Bay using HF radar-derived currents as well as drifting buoys, including newly-developed GPS drifters. Of particular interest are the coastal phenomena of sea breeze-driven currents and topography-generated internal tidal currents.

Professors E.B. Thornton and T.P. Stanton are involved in a program to develop a 3-component velocity and sediment flux probe with high temporal and spatial resolution that will provide a unique capability to estimate suspended and bedload sediment fluxes.

Professors E.B. Thornton, T. P. Stanton and T. Lippmann are developing models to predict the wave-induced three dimensional velocity field and induced sediment transport over arbitrary bathymetry in the nearshore zone under funding from ONR. Under a separate ONR contract they are evaluating wave and current surf zone models that have been transitioned to the fleet Tactical Environmental Support System.

Professor P.C. Chu, under the sponsorship of Naval Oceanographic Office is conducting a study on the coherence time and length scales that have been found from the complete hydrographic database for the Yellow Sea, which will improve the Navy's Optimum Thermal Interpolation System for the littoral zones.

ACOUSTICAL OCEANOGRAPHY

Professors R.H. Bourke, C-S. Chiu, and J.H. Miller continued their analysis of the data collected during the combined hydrographic-acoustic tomographic experiment in the Barents Sea. Current meter, ADCP, and CTD observations all indicate the importance of tidal forcing in modulating the Barents Sea Polar Front. Tomographic cross-sections of sound speed show blobs of warm water migrating upslope at two hour intervals. ONR is the sponsor of this work.

Professors R.H. Bourke and J.H. Wilson analyzed the ambient noise record from three ice-mounted buoys drifting in the Arctic Ocean north of Franz Josef Land. They are particularly interested in the effect of storms generating high noise levels. The sponsor is the Naval Oceanographic Office.

Professors R.H. Bourke and J.H. Wilson are developing a predictive ambient noise model for submarines operating in the Arctic Ocean which will forecast periods of extremely loud (>95th percentile level) and quiet (<5th percentile) noise levels. The sponsor is NPS.

Professors C-S. Chiu and L.N. Ly are developing and assessing a method to assimilate acoustic tomography data into coastal ocean models for nowcasting purposes. The research is sponsored by ONR.

Professors C-S. Chiu, J.H. Miller, and A.J. Semtner are conducting simulation studies of the variability of long-range, low-frequency sound transmission using the output from the Semtner-Chervin global eddy-resolving ocean model. This research, designed to detect signs of global warming, is sponsored by UCSD/ATOC.

Professors J.H. Miller and C-S. Chiu are investigating time-domain acoustic signal processing and propagation modeling techniques for the localization of sources of acoustic transient signals. This research is sponsored by NUWC.

AIR-SEA INTERACTION AND OCEAN TURBULENCE

Professor T.P. Stanton, with support from ONR, is involved in a research program designed to define the dynamics controlling ocean mixed layer fluxes below Arctic Leads. He also is developing an acoustic-based sediment flux probe for nearshore bottom boundary layer studies under joint Army Corps of Engineers and ONR sponsorship.

Professor R.W. Garwood, Jr. is sponsored by ONR and NPS to investigate Mediterranean Sea and Labrador Sea deep convection. Submarine observations of polar and sub-polar oceanic convection are compared with computer-simulated convection.

Professor Garwood has received an NSF grant to study the role of turbulent mixing in the Arctic system of ocean-ice-atmosphere interactions. Two forms of conditional instability for deep mixing have been discovered that may explain deep water formation in the polar seas and its impact on the global conveyor belt of deep thermohaline circulation.

NUMERICAL PREDICTION AND DATA ASSIMILATION

Under sponsorship of the National Science Foundation, Professor A.J. Semtner, Jr. is conducting simulations and assimilating satellite altimeter data using a free-surface formulation of a global eddy-resolving ocean model capable of solutions at 1/4 degree grid size. For another project supported by the Department of Energy, he has transitioned his global ocean model with 1/6 degree grid size onto massively parallel computers for use in ocean heat transport calculations related to climate studies.

Under sponsorship of NSF, Professor Batteen has extended her modeling efforts to study thermal and wind forcing effects on the eastern boundary current region off

Western Australia. This research has resulted in the first eddy-resolving model simulation of the Leeuwin Current and of eddies off Western Australia.

Professor E. Carter continued studies on data assimilation into numerical ocean models with the goal of improving mesoscale ocean forecasts. The sponsors for this work are NPS and ONR.

Under the sponsorship of NPS, Professor P.C. Chu, is developing a new diagnostic system (P-vector method) for computing 3-D ocean circulation from hydrographic data. He is also, under the sponsorship of the Office of Naval Research, implementing a new South China Sea prediction system that has been developed based on the Princeton turbulent closure model. This research is contributing to a recently initiated international South China Sea Monsoon Experiment.

MARINE OPERATIONS

Mr. P. Jessen and Professor C.A. Collins managed shipboard support for NPS at-sea research projects off the central California coast. Seventy-nine days of operations were carried out on the R/V Pt. Sur and an additional forty-six days at sea were supported on other research vessels including the USNS DeSteiguer and USNS Bartlett. Students and faculty participating in these shipboard projects included the Departments of Oceanography, Meteorology and Physics. The sponsor for this project is the Commander, Naval Oceanography Command. NPS acquired the Point Sur SOSUS array and it is being used in a variety of research projects.

Professor J. R. Clynych, with funding from NISE-West, conducted studies to improve the aircraft landing system in Antarctica using GPS and also evaluated the merging of GPS data with the TACAN system.

MODELING STUDIES OF EDDIES IN EASTERN BOUNDARY CURRENT REGIONS

M.L. Batteen, Associate Professor
C.S. Nelson, Captain, NOAA
Department of Oceanography
Sponsor: Office of Naval Research
Funding: Naval Postgraduate School

OBJECTIVE: The objective of this project is to better understand the roles of forcing mechanisms in eastern boundary current (EBC) regions, particularly the EBC regions of California, Chile, Portugal and Western Australia. The ultimate goal is to understand eddy generation mechanisms in each region well enough to provide a basis for prediction in the EBC and other dynamically similar regions.

SUMMARY: Different types of forcing (e.g., wind and thermal) have been incorporated into an existing primitive equation model. The effects of each mechanism have been analyzed by varying the type of forcing. In particular, we have focused on cases of wind and thermal forcing in a flat-bottomed ocean. Preliminary results show the development of eddies and jets. Model improvements in these studies have been to incorporate topography and finer horizontal and vertical resolution (to look at fronts).

PUBLICATIONS: Batteen, M.L., Rutherford, M.J., and Bayler, E.J., "A Numerical Study of Wind- and Thermal-Forcing Effects on the Ocean Circulation off Western Australia," Journal of Physical Oceanography, Vol. 22, pp. 1406-1433, December 1992.

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Mitchell, R.P. and Batteen, M.L., "A Numerical Study of Seasonal Wind

Forcing Effects on the California Current System," NPS Technical Report NPS-OC-93-001, March 1993.

CONFERENCE PRESENTATIONS: Tisch, T., Ramp, S., Haney, R., Collins, C., and Batteen, M., "Assessing the Energetic Interactions of Subtidal Flow on the Continental Slope off Point Sur, CA from Moored Current Meter Measurements," Eastern Pacific Ocean Conference, Mt. Hood, OR, October 1992.

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CA, December, 1992.

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OTHER: Batteen, M.L., Bacon, J.L., and Nelson, C.S., "A Numerical Study of the Effects of Seasonal Wind Forcing on the Chile Current System," Journal of Oceanography, submitted.

THESIS DIRECTED: Mitchell, R.P., LT, USN, "A Numerical Study of Seasonal Wind Forcing Effects on the California Current System," Master's Thesis, March 1993.

DOD KEY TECHNOLOGY AREA: Environmental Effects.

KEYWORDS: Coastal Oceanography, Ocean Modeling, Ocean Circulation.

**PROCESS-ORIENTED MODELING STUDIES OF EASTERN BOUNDARY CURRENT
REGIONS**

**M.L. Batteen, Associate Professor
C.S. Nelson, Captain, NOAA
Department of Oceanography
Sponsor and Funding: Office of Naval Research**

OBJECTIVE: The objectives of this project are to provide the physical understanding necessary for high resolution ocean prediction in eastern boundary current (EBC) regions, and to understand the mechanisms responsible for the formation and resolution of eddy structures in EBC regions.

SUMMARY: A high-resolution, multi-level primitive equation, regional ocean model has been used to investigate the generation and dynamics of currents and eddies in the California Current System (CCS). The process-oriented modeling studies used climatological data bases for wind and thermal forcing for the region.

PUBLICATIONS: Batteen, M.L., Mitchell, R.P., Tsai, P.T., and Nelson, C.S., "Process-Oriented Modeling Studies of Wind Forcing Effects on West Coast Ocean Circulations," Transactions of the American Geophysical Union, Vol. 73, p. 75, October 1992.

Mitchell, R.P., Batteen, M.L., and Tsai, P.T., "Visualization of Process-Oriented Modeling Studies of Wind Forcing Effects on West Coast Ocean Circulations," Transactions of the American Geophysical Union, Vol. 73, p. 75, October 1992.

Tisch, T., Ramp, S., Haney, R., Collins, C., and Batteen, M. "Assessing the Energetic Interactions of Subtidal Flow on the Continental Slope off Point Sur, CA from Moored Current Meter Measurements,"

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Mitchell, R.P. and Batteen, M.L., "A Numerical Study of Seasonal Wind Forcing Effects on the California Current System," NPS Technical Report NPS-OC-93-001, March 1993.

CONFERENCE PRESENTATION: Batteen, M.L., Mitchell, R.P., Tsai, P.T., and Nelson, C.S., "Process-Oriented Modeling Studies of Wind Forcing Effects on West Coast Ocean Circulations," American Geophysical Union Fall Meeting, San Francisco, CA, December 1992.

Mitchell, R.P., Batteen, M.L., and Tsai, P.T., "Visualization of Process-Oriented Modeling Studies of Wind Forcing Effects on West Coast Ocean Circulations," American Geophysical Union Fall Meeting, San Francisco, CA, December 1992.

Tisch, T., Ramp, S., Haney, R., Collins, C., and Batteen, M., "Assessing the Energetic Interactions of Subtidal Flow on the Continental Slope off Point Sur, CA from Moored Current Meter Measurements," Eastern Pacific Ocean Conference, Mt. Hood, OR, October 1992.

OTHER: Batteen, M.L., Bacon, J.L., and Nelson, C.S., "A Numerical Study of the Effects of Seasonal Wind Forcing on the Chile Current System," Journal of Oceanography, submitted.

DOD KEY TECHNOLOGY AREA: Environmental Effects.

KEYWORDS: Coastal Oceanography,
Ocean Modeling, Ocean Circulation.

EDDY-RESOLVING MODELING STUDIES OF THE LEEUWIN CURRENT

M.L. Batteen, Associate Professor

Department of Oceanography

Sponsor and Funding: National Science Foundation

OBJECTIVE: The overall goals of this research are to carry out process-oriented modeling studies to investigate the generation and stability of currents and eddies in the Leeuwin Current region, and to better describe the contributing forcing mechanisms and their relative importance. To carry out these goals, we proposed to extend the eddy-resolving, process-oriented modeling studies of Batteen and Rutherford (1990) and Batteen *et al.* (1992) by adding the following features to the model: (1) continuously forced ocean thermal forcing and ocean wind forcing; (2) seasonally forced ocean thermal forcing and wind forcing; (3) bottom forcing capability; and (4) extension of the model domain to include the Southern Australia coastal region. These features will allow us to systematically investigate the roles of ocean and thermal forcing, and bottom topography, in the generation and stability of currents and eddies in the Leeuwin Current region, and to better describe the contributing forcing mechanisms and their relative importance.

SUMMARY: During this first year of funding, we have examined the effects on the Leeuwin Current off Western Australia when the first two features are added to the model, i.e., (1) continuously forced ocean thermal forcing and wind forcing; and (2) seasonally forced ocean thermal forcing and wind forcing.

Preliminary results show the following:

The combination of wind and thermal cycles allows the formation of the North West Shelf waters and subsequently triggers the release of poleward flowing North West Shelf waters. This additional forcing produces a strong surge in poleward flow during the austral autumn. A nonlinear feedback mechanism acts to extend the duration of this flow through the austral winter.

Comparisons with observations show that the model is able to closely follow the seasonal variations in the strength and character of the Leeuwin Current. The associated undercurrent and flow variability (eddies) are also reproduced with close resemblance to observations.

PUBLICATIONS: Batteen, M.L., Rutherford, M.J. and Bayler, E.J., "A Numerical Study of Wind- and Thermal-Forcing Effects on the Ocean Circulation off Western Australia," Journal of Physical Oceanography, Vol. 22, pp. 1406-1433, December 1992; Research Activities in Atmospheric and Oceanic Modeling, George J. Boer, ed., WMO/JSC Working Group on Numerical Experimentation, Report No. 18, p. 8.19, January 1993.

DOD KEY TECHNOLOGY AREA: Environmental Effects.

KEYWORDS: Coastal Oceanography,
Ocean Modeling, Ocean Circulation.

CHAIR IN ARCTIC MARINE SCIENCE

R.H. Bourke, Professor

Department of Oceanography

**Sponsor and Funding: Office of Naval Research and the
Naval Postgraduate School**

OBJECTIVE: To foster oceanographic research in the Arctic, acquaint naval officer students with Arctic problems, reduce results of pure research to operational usage and publicize Navy interest in the Arctic.

SUMMARY: Professor Bourke served as administrator of the Chair handling such details as selecting Chair candidates, writing IPA's and proposals and setting up visits and seminars for the Chair incumbent. Dr. James H. Wilson, a private consultant, was the Chair incumbent during 1993. He had a particularly busy year at NPS being heavily involved in teaching and research. In addition to lecturing in the polar oceanography course, he taught an ocean acoustics course which he modified to increase the subject matter related to shallow water acoustics. He is the thesis advisor for five students and significantly assisted the research endeavors of two others. In response to the changing Arctic warfare threat, he conducted an extensive review of the state of knowledge of Arctic shallow water acoustic propagation and ambient noise capability based upon observations and modeling. He also

wrote two scholarly publications, each now in the final stages of the review process. He attended several other major conferences, presenting papers at each.

PUBLICATION: Bourke, R. H., Wilson, J.H., and Buck, B.M., "Survey of Acoustic Results for Arctic Shallow Water," NUWC-NPT Technical Document 10,485, August 1993.

CONFERENCE PRESENTATIONS: Wilson, J.H., "Tomographic Inverse Beamforming," Annual Fall Meeting of the Acoustical Society of America, Denver, CO, November 1993.

Wilson, J.H., "Backus-Gilbert Inverse Theory Applied to the Inverse Beamforming Integral Equation," Naval Research Laboratory, Washington, March 1993.

Wilson, J.H., "Wilson Shallow Water Frequency Dispersion Phenomenon," Naval Air Warfare Center, Warminster, PA, June 1993.

DOD KEY TECHNOLOGY AREA: Environmental Effects.

KEYWORDS: Arctic Ocean, Sea Ice, Ambient Noise.

ANALYSIS OF UNDERICE AMBIENT NOISE MEASURED BY DRIFTING BUOYS

R.H. Bourke, Professor

R.G. Paquette, Emeritus Professor

Department of Oceanography

Sponsor and Funding: Naval Oceanographic Office

OBJECTIVE: The purpose of this project was to analyze the ambient noise data acquired from three ice-mounted buoys which drifted with the ice from April 1992 to the present in the Arctic Ocean to the north of Franz Josef Land.

SUMMARY: Data have been acquired from NAVO for buoy position and noise amplitude. It appears that two of the three buoys have grounded (November 1993) in the shallow waters northeast of Franz Josef Land. Data editing to fill data gaps, remove spurious data and to increment noise levels and positions on an hourly basis have been completed. Data analysis and correlation with storm

passage will continue in 1994. A thesis describing the results of this work will be published in September 1994. A paper describing the noise field from three noise buoys drifting near Svalbard was published.

PUBLICATION: Bourke, R.H. and Parsons, A.R., "Ambient Noise Characteristics of the Northwestern Barents Sea," Journal of Acoustical Society of America, Vol. 94, No. 5, pp. 2799-2808, 1993.

DOD KEY TECHNOLOGY AREA: Environmental Effects.

KEYWORDS: Arctic Ocean, Barents Sea, Sea Ice, Ambient Noise.

PHYSICAL OCEANOGRAPHY OF THE ARCTIC OCEAN

R.H. Bourke, Professor

R.G. Paquette, Emeritus Professor

**Sponsors: Arctic Submarine Laboratory (NUWC) and the
Naval Postgraduate School**

Funding: Naval Postgraduate School

OBJECTIVE: The purpose of this project was to analyze the conductivity-temperature-depth (CTD) data collected by a submarine operating in the Arctic Ocean during March and April in order to establish the scientific usefulness of such data and to identify procedures that might yield even more useful results.

SUMMARY: Raw CTD data on diskettes have been processed in 6-hour time series and plotted to visually locate interesting oceanographic phenomena such as eddies, fronts and interbasin variability. The data have been corrected for substantial temperature and salinity errors based on comparison with vertical CTD casts made from a manned-ice camp. Near the ice camp over a period of about 25 days, a series of both warm and cold core eddies have been identified. From the ascents/descents of the submarine, vertical CTD profiles

have been constructed. These have assisted in our eddy analysis and in illustrating interbasin differences in water properties. Due to vessel depth restrictions, the results of this work have had to be reported at the SECRET level as an NPS technical report. The results of this work served as a major impetus for conducting a similar eddy survey from a submarine in August 1993.

PUBLICATION: Paquette, R.G. and Bourke, R.H., "The Use of a Submarine-Mounted Conductivity-Temperature-Depth Recorder in the Arctic (U)," NPS Technical Report NPS-OC-93-003, September 1993.

DOD KEY TECHNOLOGY AREA: Environmental Effects.

KEYWORDS: Arctic Ocean, Beaufort Sea, CTD, Arctic Eddies.

DATA ASSIMILATION MODELING

E.F. Carter, Assistant Professor

Department of Oceanography

Sponsor and Funding: Office of Naval Research

OBJECTIVE: This project considers the problem of assimilating observations of ocean data into an evolving numerical model of the ocean dynamics.

SUMMARY: Progress of great significance on this project was achieved during this period of time. The introduction of stochastic calculus to the problem has allowed solving all the scientific issues. While there are some important technical issues on this problem that need to be address, the scientific problem has now been solved. A scientific paper describing this achievement is now in preparation for publication in a professional journal.

PUBLICATIONS: Song, T., Rossby, T., and Carter, E.F., "Lagrangian Studies of Fluid Exchange between the Gulf Stream and the Surrounding Waters," Journal of Physical Oceanography, in

press.

Rossby, T., Fontaine, J., and Carter, E.F., "The f/h Float - Measuring Stretching Vorticity Directly," Deep Sea Research, in press.

CONFERENCE PRESENTATION: Carter, E.F., "Data Assimilation into Nonlinear Stochastic Models," Department of Oceanography, NPS, October 1993.

OTHER: Carter, E.F., "The Use of Simulated Annealing for Nonlinear Estimation."

Carter, E.F., Miller, R.N. and Goodlett, S.B., "Data Assimilation into Nonlinear Stochastic Models."

DOD KEY TECHNOLOGY AREA: Environmental Effects.

KEYWORDS: Data Assimilation.

NAVAL OCEAN ANALYSIS AND PREDICTION

P.C. Chu, Associate Professor

Department of Oceanography

Sponsor and Funding: Naval Postgraduate School

OBJECTIVE: The goal of this project was to develop a new Naval Ocean Analysis and Prediction Lab to meet the Navy's requirement of ocean prediction.

SUMMARY: A new diagnostic system has been developed for three dimensional ageostrophic ocean circulations by using the hydrographic data sets. This new method was proved to be a useful tool for ocean analysis. Two reimbursable funds from the Navy were obtained.

PUBLICATIONS: Chu, P.C., "Three Dimensional Pseudovorticity Field in the West Spitsbergen Current," Polar Meteorology & Oceanography, Vol. 10, pp. 117-120, 1992.

Chu, P.C., "Three Dimensional Eastern Greenland Sea Circulation Computed from a CTD Data Set," Ocean-Atmosphere-Ice Interaction, Vol. 1, pp. 61-64, 1992.

Chu, P.C., Konstandinidis, S., Jessen, P., and Collins, C.A., "C-Vector Method derived Three Dimensional Circulation in Farallone National Sanctuary," EOS, Transactions, Vol. 89, 1992.

Chu, P.C. and Kuo, Y.H., "South Atlantic Three Dimensional Pseudovorticity Field Computed from Hydrographic and Surface Air Data Sets," Southern Hemisphere Meteorology and Oceanography, Vol. 4, pp. 52-53, 1993.

Chu, P.C., "Intrinsic Thermodynamic

Time-Scales of the Atmosphere-Ocean-Cryosphere Climate System," Global Change Studies, Vol. 4, pp. 433-438, 1993.

Chu, P.C., "Generation of Low-Frequency Unstable Modes in a Coupled Equatorial Troposphere and Ocean Mixed Layer Model," Journal of Atmospheric Sciences, pp. 731-749, 1993.

CONFERENCE PRESENTATIONS: Chu, P.C., "Intrinsic Thermodynamical Time Scales," Fourth Symposium on Global Change Studies, American Meteorological Society, Anaheim, CA, 17-22 January 1993.

Chu, P.C. and Kuo, Y.H., "South Atlantic Three Dimensional Pseudovorticity Field," Fourth International Conference on Southern Hemisphere Meteorology & Oceanography, Hobart, Australia, 29 March - 2 April 1993.

Chu, P.C., "Three Dimensional Vorticity Field in Atlantic Ocean," The Oceanography Society Meeting, Seattle, WA, 12-17 April 1993.

OTHER: Chu, P.C., "P-Vector Method for Determining North Atlantic Circulation from Hydrographic Data," submitted to Journal of Physical Oceanography.

DOD KEY TECHNOLOGY AREA: Environmental Effects.

KEYWORDS: Modeling.

SOUTH CHINA SEA OCEAN PREDICTION SYSTEM

P.C. Chu, Associate Professor

Department of Oceanography

Sponsor and Funding: Office of Naval Research

OBJECTIVE: The goal of this project was to develop an ocean prediction system for the South China Sea and to investigate its effect on the coupled atmosphere-ocean system in the equatorial Pacific Ocean.

SUMMARY: A new South China Sea prediction system has been developed based on the Princeton turbulent closure model. This research also contributes to a recently initiated international South China Sea Monsoon Experiment.

PUBLICATIONS: Chu, P.C. and Kuo, Y.H., "South Atlantic Three Dimensional Pseudovorticity Field Computed from Hydrographic and Surface Air Data Sets," Southern Hemisphere Meteorology and Oceanography, Vol. 4, pp. 52-53, 1993.

Chu, P.C., "Generation of Low-Frequency Unstable Modes in a Coupled Equatorial Troposphere and Ocean

Mixed Layer Model," Journal of Atmospheric Sciences, pp. 731-749, 1993.

Li, C.C., Chu, P.C., Ko, D.S., and Mooers, C.N.K., "A Numerical Model for South China Sea Prediction," American Geophysical Union Transactions, p. 352, 1993.

CONFERENCE PRESENTATIONS: Chu, P.C. and Kuo, Y.H., "South Atlantic Three Dimensional Pseudo-Vorticity Field," Fourth International Conference on Southern Hemisphere Meteorology & Oceanography, Hobart, Australia, 29 March - 2 April 1993.

Chu, P.C., Li, C.C., Ko, D.S., and Mooers, C.N.K., "South China Sea Ocean Prediction System," American Geophysical Union Fall Meetings, San Francisco, CA, 6-10 December 1993.

DOD KEY TECHNOLOGY AREA: Environmental Effects.

KEYWORDS: Modeling.

LITTORAL ZONE NAVAL OCEAN PREDICTION SYSTEM

P.C. Chu, Associate Professor

Department of Oceanography

Sponsor and Funding: Naval Oceanographic Office

OBJECTIVE: The goal of this multi-year project was to improve littoral zone naval ocean prediction systems in the southeast Asian regional seas by (1) studying the relationship between the sea surface temperature and subsurface thermal structure, (2) investigating the horizontal coherence length scales, and (3) implementing ocean circulation models.

SUMMARY: The complete database for the Yellow Sea temperature and salinity (approximate 50,000 profiles) has been installed and processed. All the necessary software for the research has been transferred from NAVOCEANO to NPS as well as built up in NPS. A numerical model

for the South China Sea has also been established.

PUBLICATION: Li, C.C., Chu, P.C., Ko, D.S., and Mooers, C.N.K., "A Numerical Model for South China Sea Prediction," American Geophysical Union Transactions, p. 352, 1993.

CONFERENCE PRESENTATION: Chu, P.C., Li, C.C., Ko, D.S., and Mooers, C.N.K., "South China Sea Ocean Prediction System," American Geophysical Union Fall Meetings, San Francisco, CA, 6-10 December 1993.

DOD KEY TECHNOLOGY AREA: Environmental Effects.

KEYWORDS: Modeling.

COASTAL OCEAN ACOUSTIC TOMOGRAPHY DATA ASSIMILATION

C.-S. Chiu, Associate Professor

Department of Oceanography

Sponsor and Funding: Office of Naval Research

OBJECTIVE: The objective of this project is to develop a small-domain, high-resolution coastal ocean circulation model with efficient data integration and assimilation capabilities for ocean nowcasting. This system will optimally assimilate various types of data including remote sensing and acoustic tomographic measurements.

SUMMARY: We have developed a curvilinear coastal ocean circulation model based on the Gulf Stream model of Mellor. A major model improvement that we have accomplished was the use of grid generation techniques to focus the computation and resolution in the shallow water areas. This coastal model is working very well for the Mediterranean with high resolution (221X71). We are currently simulating a tomographic array in a 200x200 km region (the Gulf of Sirte off Libya) and conducting identical-twin data assimilation computer experiments

using the coastal model and tomographically derived temperature slices. Direct insertion method is being investigated at this moment. We will also investigate nudging methods by the end of this year. Next year, we will investigate statistically optimal methods that would assimilate acoustic tomography travel time data directly into our coastal model. More importantly, we will also address the limitation and practicality issues next year.

CONFERENCE PRESENTATION: Ly, L.N., Luong, P., and Chiu, C.-S. "Application of Grid Generation Techniques for Coastal Ocean Modeling," Fall AGU Meeting, San Francisco, CA, 1993.

DOD KEY TECHNOLOGY AREA: Sensors, Electronic Devices, Environmental Effects.

KEYWORDS: Coastal Ocean Model, Acoustic Tomography, Data Assimilation.

BARENTS SEA TOMOGRAPHY EXPERIMENT AND DATA ANALYSIS

C.-S. Chiu, Associate Professor

R.H. Bourke, Professor

Department of Oceanography

J.H. Miller, Assistant Professor

Department of Electrical and Computer Engineering

Sponsor and Funding: Office of Naval Research

OBJECTIVE: In August 1992, a shelf tomography experiment was conducted in the Barents Sea east-southeast of Bear Island. The objective of the experiment was to study the local dynamics of the Barents Sea Polar Front using acoustic tomography coupled with traditional oceanographic techniques. A vertical telemetered hydrophone array and three tomography sound sources were deployed in a square configuration enclosing the frontal zone.

SUMMARY: Analysis of the hydrographic data in 1993 was centered on defining the temporal and spatial characteristics of the Bear Island shelf break front; analyzing the nine current meter records to establish mean currents, their spatial variability, spectral disposition and kinetic (eddy) energy content; describing the water mass characteristics and geostrophic circulation pattern; and examining the relative components of the tidal forcing. Detailed bathymetric and sound speed data between the acoustic source and vertical receiving array were determined for use in the tomographic inversion process. Space-time signal processing techniques were used to detect, identify and track individual acoustic ray and modal arrivals from one of the sources to the vertical array along a cross-front section. A hybrid stochastic ray-mode inverse method was developed for mapping the cross-frontal thermal structure in this complex shallow shelf environment, where modes are strongly

coupled and ray geometries are complex. This method is based on spectral decomposition of the solution and minimization of an objective function. The input data are the travel time perturbations of the beamformed rays and modes. This technique provides for optimal sound speed maps having minimum mean square errors. In addition, the technique gives error and resolution estimates which are essential to oceanographic interpretation of the tomographic images. A time series of cross-frontal images of ocean temperature was produced by applying this technique to the acoustic travel time perturbation data. These tomographically derived temperature distributions, covering the ocean from the surface to the bottom (with a nominal depth of 200 m) over a range of 35 km, were produced every 5 min over a tidal period. The distributions show thermal structures consistent with vertical turbulent mixing in the lower portion of the front on a time scale of about 2 hours, wave-like motions in the thermocline, and frontal oscillations consistent with local barotropic and baroclinic tidal forcing.

PUBLICATIONS: Chiu, C-S., Miller, J.H., and Lynch, J.F., "Inverse Techniques for Coastal Acoustic Tomography," in Proceedings of the 1993 International Conference on Theoretical and Computational Acoustics, 1993, accepted.

Miller, J.H., Chiu, C-S., and Lynch, J.F., "Signal Processing for Coastal

Acoustic Tomography," in Proceedings of the 1993 International Conference on Theoretical and Computational Acoustics, 1993, accepted.

Von Der Heydt, K., Kemp, J., Lynch, J.F., Miller, J.H., and Chiu, C.-S., "Shallow Water Tomography in the Barents Sea using LAN Telemetry," Woods Hole Oceanographic Institution Technical Report, October 1992.

Von Der Heydt, K., Kemp, J., Lynch, J.F., Miller, J.H., and Chiu, C.-S., "Barents Sea Shallow Water Tomography," Sea Technology, pp. 55-59, August 1993.

CONFERENCE PRESENTATIONS: Chiu, C.-S., Miller, J.H., and Lynch, J.F., "Inverse Techniques for Coastal Acoustic Tomography," International Conference on Theoretical and Computational Acoustics, Mystic, CT, 5-9 July 1993. (Invited).

Miller, J.H., Chiu, C.-S., and Lynch, J.F., "Signal Processing for Coastal Acoustic Tomography," International Conference on Theoretical and Computational Acoustics, Mystic, CT, 5-9 July 1993. (Invited).

Lynch, J.F., Chiu, C.-S., and Miller, J.H., "Forward Modeling for Coastal Acoustic Tomography," International Conference on Theoretical and Computational Acoustics, Mystic, CT, 5-9 July 1993. (Invited).

Bourke, R.H., Chiu, C.-S., Lynch,

J.F., Miller, J.H., Muench, R.D., and Plueddemann, A.J., "Initial Results From the Barents Sea Polar Front Experiment," Fall AGU Meeting, San Francisco, CA, 7-11 December 1992.

Muench, R.D., Lynch, J.F., Plueddemann, A.J., Bourke, R.H., Chiu, C.-S., and Miller, J.H., "A Physical Oceanographic and Acoustic Tomographic Survey of a Shelf/Slope Front," 3rd Scientific Meeting of the Oceanography Society, Seattle, WA, April 1993.

THESES DIRECTED: Sagos, George A., "A Three-Dimensional Coupled Normal Mode Model for Sound Propagation in Shallow Water with Irregular Bottom Bathymetry," MS in Engineering Acoustics and MS in Electrical Engineering, December 1992.

Mykyta, John L., "Prediction of Planewave Beamformed Arrival Structure for the Acoustic Transmission in the 1992 Barents Sea Polar Front Experiment," MS in Meteorology and Physical Oceanography, September 1993.

OTHER: Video movie of the tomographic inverse solution.

DOD KEY TECHNOLOGY AREA: Sensors, Electronic Devices, Environmental Effects.

KEYWORDS: Shallow Water, Acoustics, Tomography, Frontal Dynamics.

GLOBAL ACOUSTIC PATH VARIABILITY STUDY

C.-S. Chiu, Associate Professor

A.J. Semtner, Professor

Department of Oceanography

J.H. Miller, Assistant Professor

Department of Electrical and Computer Engineering

Sponsor and Funding: UCSD - ATOC Project Office

OBJECTIVE: The objective of this project is to provide acoustic modeling support for the Acoustic Thermometry of Ocean Climate (ATOC) Project. This international research effort involves making decadal measurements of cross-basin acoustic travel-time variability to monitor greenhouse warming.

SUMMARY: Specifically, our modeling work simulates the influence of ocean fronts, eddies and seasonal cycles on cross-basin acoustic transmissions using the Semtner-Chervin Eddy-Resolving Global General Circulation Model (SCGCM) and the Hamiltonian Acoustic Raytracing Program for the Ocean (HARPO). The simulated acoustic variability is analyzed to assist ATOC in the selection of optimal source and receiver sites.

PUBLICATIONS: Lynch, J.F., Newhall, A.E., Chiu, C.S., and Miller, J.H., "Three-Dimensional Ray Acoustics in a Realistic Ocean," in Coupled Ocean Prediction and Acoustic Propagation Models, Robinson and Lee, eds., American Institute of Physics, 1993.

Chiu, C.S., Semtner, A.J., Ort, J.H., and Miller, J.H., "A Ray Variability Analysis of Sound Transmission from Heard Island to California," Journal of Acoustical Society of America, 1993, accepted.

Chiu, C-S., "Downslope Modal Energy Conversion," Journal of Acoustical Society of America, in press.

Chiu, C-S., "Downslope Modal Energy Conversion," ATOC Occasional Notes, No. 10., 1993.

CONFERENCE PRESENTATION: Denner, W.W., Lashkari, K., Miller, J.H., and Chiu, C.-S., "Possible Uses of Submarine Canyons in Acoustic Thermometry," New Orleans ASA Meeting, 31 October - 4 November 1992.

DOD KEY TECHNOLOGY AREA: Sensors, Environmental effects.

KEYWORDS: Climate, Global Ocean, Acoustic Thermometry.

**GPS ANTARCTIC LANDING SYSTEM: ACCURACY AND
IONOSPHERIC EFFECTS STUDY**

**J.R. Clynch, Research Professor
Department of Oceanography**

Sponsor and Funding: NIST-West, Vallejo, CA

OBJECTIVE: The aircraft landing system at the US bases in Antarctica must be replaced in the next 3-4 years. GPS is the primary candidate system for use in this remote site. There are several special features about the geometry and environment that need to be addressed before a firm decision is made to use GPS for this flight critical application. The objective of this work is to design and execute experiments and studies to provide the necessary information for that decision.

SUMMARY: An experiment deployed to McMurdo Antarctica from January through December 1992 and data were returned to NPS 1992 for analysis. These data showed that at McMurdo, the occurrence of ionosphericly induced signal problems was essentially non-existent.

In addition to the data from the NPS experiment, GPS data taken at South Pole Station by the US Geological Survey during 1992 was obtained from their archives. This did show tracking anomalies that need careful further analysis. The difference in stations is probably due to their different locations in magnetic co-

ordinates. McMurdo is very near the magnetic pole and in the polar cap region while South Pole Station is in the southern auroral oval. To further study this, some of the NPS equipment was moved to South Pole Station for data collection in the 1993/4 seasons.

During this year flight test of a prototype GPS landing systems were performed at PT Mugu NAS by VXE6. The data from these tests was analyzed. In addition, an experiment on the tracking of the movement of the McMurdo runway (which is on an ice sheet) was deployed.

As part of the tracking of the commercial developments of GPS landing system, the principle investigator served on a committee developing specifications for Category I GPS landing system. The report of that committee is being transformed into a order by the FAA expected in early 1994.

DOD KEY TECHNOLOGY AREA: Electronic Devices, Environmental Effects.

KEYWORDS: GPS, Aircraft Landing Systems.

CALIFORNIA UNDERCURRENT STUDIES

C.A. Collins, Chairman and Professor
N. Garfield, Research Assistant Professor

E. Carter, Assistant Professor

R. Paquette, Emeritus Professor

Department of Oceanography

Sponsor and Funding: Office of Naval Research and the
Naval Postgraduate School

OBJECTIVE: To understand the dynamics and kinematics of the California Undercurrent off Central California. The following questions formed the basis for our investigation. What is the mean pattern of poleward and equatorward flow off Pt. Sur? What are the poleward transports of heat and salt? Is the California Undercurrent continuous along the west coast, or is it a series of discontinuous currents? Is there a reference level that can be used for geostrophic calculations? How can various velocity measuring techniques be used in a consistent manner?

SUMMARY: The California Current and Undercurrent were observed in each of 19 research cruises between April 1998 and April 1991. The Undercurrent core location varied between 43 and 70 km offshore. The depth of the core of the current was found around a depth of 200 m. The extent of poleward flow was usually within a triangular shaped region, extending from the surface nearshore down to at least 700 m (often much deeper) along the slope, thence to the surface approximately 70 km offshore. The computed poleward transport varied from 3 to 7 Sv. The north-south component of flow was often barotropic in character across the continental slope, but the east-west component of flow was strongly sheared, with the flow in the upper 200 m exceeding the flow at depth. This variability was from eddies present along the sampling line.

To investigate the continuity of the alongshore flow, we began deploying RAFOS floats from a location east of the Farallon Islands and over the continental slope. While we are just beginning to receive data from the floats, two floats remained in the Undercurrent and were carried north of 42 N.

Final processing of Pegasus and CTD data were completed during 1993. Research papers are now being written.

PUBLICATION: Garfield, N., Rago, T.A., Schnebele, K.J., and Collins, C.A., "Evidence of a Turbidity Current in Monterey Submarine Canyon associated with the 1989 Loma Prieta Earthquake," Continental Shelf Research, in press.

CONFERENCE PRESENTATION: Rischmiller, F.W., Garfield, N., Collins, C.A., and Rago, T.A., "Seasonal Variability of Ocean Currents off Pt. Sur, California from May 1988 to April 1991," 1993 Fall Meeting, American Geophysical Union, San Francisco, CA, 6 December 1993.

THESES DIRECTED: Rischmiller, F.W., LT, USN, "Seasonal Variability of Ocean Currents off Pt. Sur, California from May 1988 to April 1991," Master's Thesis, December 1993.

Negron, A.J., LCDR, USN, "Measurements of Currents Across the Continental Margin off Point Sur,

California, during March 1989"
Master's Thesis, March 1993.

DOD KEY TECHNOLOGY AREA: Environ-
mental Effects.

KEYWORDS: Ocean Circulation,
Absolute Velocity Measurements,
Eastern Pacific Circulation.

PLUME TRACKING WITH RAFOS FLOATS

**C.A. Collins, Chairman and Professor
N. Garfield, Research Assistant Professor
Department of Oceanography
Sponsor and Funding: National Oceanic,
Atmospheric Administration and
National Science Foundation**

OBJECTIVE: The objective of this research was to provide scientists involved in the North Pacific VENTS program with subsurface ocean drifters which could be used to tag and track subsurface ocean thermal plumes emitted from the mid-ocean ridge area.

SUMMARY: In early July 1993, unusual seismic activity on the Juan de Fuca ridge was detected by NOAA scientists. A Canadian research vessel was diverted to the area and measured a large subsurface thermal plume over the ridge. Three RAFOS subsurface Lagrangian ocean drifter floats were subsequently prepared and ballasted. An August 1993 cruise to the Juan de Fuca Ridge carried these floats with the intent of launching

the floats into the subsurface thermal plume. The plume was not found, but one of the floats was launched. This float will surface in one year (July 1994) and will provide the first deep ocean Lagrangian measurements in the north eastern Pacific. The other two floats will be carried and deployed on future VENTS cruises.

OTHER: This work was a quick response effort that resulted from unusual seismic activity on Juan de Fuca ridge.

DOD KEY TECHNOLOGY AREA: Sensors,
Environmental Effects.

KEYWORDS: Deep Ocean Circulation,
Oceanic Hydrothermal Plumes.

**CIRCULATION ON THE CONTINENTAL SHELF AND SLOPE NEAR THE
FARALLON ISLANDS, CA**

**C.A. Collins, Chairman and Professor
S.R. Ramp, Associate Research Professor
N. Garfield, Assistant Research Professor
L.K. Rosenfeld, Assistant Research Professor
M. Noble, USGS, Menlo Park, CA
F. Schwing, Visiting Professor
Department of Oceanography**

Sponsor: WESTDIV, Naval Facilities Engineering Command

Funding: U.S. Environmental Protection Agency,

U.S. Army Corp of Engineerings,

WESTDIV and USGS

OBJECTIVE: To describe the ocean circulation over the continental shelf and slope near the Farallon Islands, CA, particularly as it pertains to the dispersal of dredged material which may dumped in the area at ocean dumpsites whose exact location has not yet been designated. We will provide scientific input to managers at WESTDIV and EPA who will be making the site designation decisions.

SUMMARY: The approach is to use a series of 5 high-resolution shipboard hydrographic and ADCP surveys to resolve the spatial variability over the study region at different times, and combine this information with data from six current meter moorings in the region which resolve the temporal variability well but have limited spatial coverage. Satellite AVHRR data is used extensively to interpret both the moored and shipboard results. In the analyses, Drs. Collins, Schwing, and Garfield focused on the hydrographic data, Drs. Rosenfeld and Ramp worked on the ADCP data, and Drs. Ramp and Noble

performed the current meter data analysis. Results have appeared in the form of data reports, and technical reports to the sponsors. Currently, we are preparing journal publications for the refereed literature.

CONFERENCE PRESENTATION: Noble, M. and Ramp, S.R., "The Subtidal Current Field Observed over the Continental Slope near the Farallones Islands, CA," EPOC, October 1993.

THESES DIRECTED: Hays, Kevin, LT, USN, "A Water Mass Analysis of the 1991-1992 El Niño Signal in the Farallon Islands Region," Master's Thesis, March 1993 (Ramp, advisor).

Montenegro, Gonzalo, LT, Ecuador Navy, "Three Dimensional Vorticity Field in the California Current System," Master's Thesis, March 1993.

DOD KEY TECHNOLOGY AREA: Sensors.

KEYWORDS: Environmental Effects, Littoral and Ocean Circulation.

MARINE OPERATIONS

C.A. Collins, Chairman and Professor

P. Jessen, Oceanographer

Department of Oceanography

Sponsor: Commander, Naval Oceanography Command

Funding: Naval Postgraduate School

OBJECTIVES: To provide administrative and logistical support for shipboard operations necessary for research and instruction.

SUMMARY: The marine operations program supported 66 days at sea in FY93 on the R/V Point Sur.

Activities included the Operational Oceanography course (OC 3570) in spring and fall quarters and Descriptive Physical Oceanography in fall, winter, spring and summer quarters. Eastern Boundary Current cruises were carried out in April and May, and meteorological cruises were staged in October and August.

The marine operations program maintains equipment which is routinely used at sea: CTDs, XBTs, and shipboard data acquisition system. Two NBIS Mark III CTDs were transferred to NPS from the Naval Coastal Systems Lab and were refurbished for our use. Salinometers and calibration facilities are also maintained. The program actively interfaces with other local ship users through the Central California Consortium (CENCAL), with other national academic ship users through the University National Laboratory Systems (UNOLS), and with Navy research vessels through the Naval Oceanographic Office. Two mooring buoys are maintained near the Coast Guard pier in Monterey Harbor for use by academic research vessels.

Activities begun at the entrance to the Gulf of California on USNS

DeSteiguer in April 1992 have continued. The fall OC3570 course was staged from La Paz, B.C., Mexico, repeating the DeSteiguer measurements over the Christmas/New Year holiday. Data from both cruises have been analyzed, revealing strong inflow into the Gulf along Sinaloa with outflow along Baja California. Results have been discussed by Spearman (1993) and Garfield, et al (1993). Additional measurements are planned for 1994 using Mexican research vessels.

PUBLICATIONS: Chu, P.C., "Three Dimensional Pseudovorticity Field in the West Spitsbergen Current," Polar Meteorology & Oceanography, Vol. 10, pp. 117-120, 1992.

Chu, P.C., "Three Dimensional Eastern Greenland Sea Circulation computed from a CTD Data Set," Ocean-Atmosphere-Ice Interaction, Vol. 1, pp. 61-64, 1992.

Chiu, C.S., Semtner, A.J., Ort, J.H., and Miller, J.H., "A Ray Variability Analysis of Sound Transmission from Heard Island to California," Journal of the Acoustical Society of America, 1993, accepted.

Garfield, N.A., Rago, T.A., Schnebele K.J., and Collins, C.A., "Evidence of a Turbidity Current in Monterey Submarine Canyon associated with the 1989 Loma Prieta Earthquake," Continental Shelf Research, in press.

The Leadex Group, including T. P. Stanton "the LeadEx Experiment," EOS, Vol. 74, No. 35, August 1993.

Miller, J.H., Lynch, J.F., Chiu, C.S., Westreich, E.L., Gerber, J.S., Hippenstiel, R., and Chaulk, E., "Acoustic Measurements of Surface Gravity Wave Spectra in Monterey Bay using Mode Travel Time Fluctuations," Journal of the Acoustical Society of America, Vol. 94, No. 2.1, pp. 954-974, 1993.

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CONFERENCE PRESENTATIONS: Bourke, R.H., Chiu, C-S., Lynch, J.F., Miller, J.H., Muench, R.D., and Plueddemann, A.J., "Initial Results from the Barents Sea Polar Front Experiment," Fall AGU Meeting, San Francisco, CA, 7-11 December 1992.

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Chu, P.C., Konstandinidis, S., Jessen, P., and Collins, C.A., "C-Vector Method derived Three Dimensional Circulation in Farallones

National Sanctuary," 1993 Fall National Meeting, American Geophysical Union, San Francisco, CA, 6 December 1993.

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Muench, R.D., Lynch, J.F., Plueddemann, A.J., Bourke, R.H., Chiu, C.-S., and Miller, J.H., "A Physical Oceanographic and Acoustic Tomographic Survey of a shelf/Slope Front," 3rd Scientific Meeting of the Oceanography Society, Seattle, WA, April 1993.

Noble, M. and Ramp, S.R., "The Subtidal current field observed over the Continental Slope near the Farallones Islands, CA," EPOC, October 1993.

Paduan, J.D. and Cook, M.S., "Drifting Buoy Observations of Eddies in the Eastern Boundary Current," 40th Eastern Pacific Conference, Stanford Sierra Camp, Fallen Leaf, CA, 21-23 October 1993.

Rischmiller, F.W., Garfield, N., Collins, C.A., and Rago, T.A., "Seasonal Variability of Ocean Currents off Pt. Sur, California from May 1988 to April 1991," 1993 Fall National Meeting, American Geophysical Union, San Francisco, CA, 6 December 1993.

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Wind Waves Using Coherent Acoustic Profilers," Symposium on The Air-Sea Interface, Marseilles, France, 24-30 June 1993.

THESES DIRECTED: Chumbinho, R.P.A., LT, Portuguese Navy, "Objective Analysis of a Coastal Eddy Using Satellite AVHRR and In Situ Hydrographic Data," Master's Thesis, September 1993.

Cross, P.S., LT, USN, "A Comparison of Observed and Modeled Coastal Diurnal Mixed Layer Behavior," Master's Thesis, December 1993.

Foster, M.D., LCDR, USN, "Evolution of Diurnal Surface Winds and Surface Current for Monterey Bay," Master's Thesis, December 1993.

Hays, Kevin, LT, USN, "A Water Mass Analysis of the 1991-1992 El Niño Signal in the Farallon Islands Region, March 1993," Master's Thesis, March 1993.

Montenegro, Gonzalo, LT, Ecuador Navy, "Three Dimensional Vorticity Field in the California Current System," Master's Thesis, March 1993.

Negron, A.J., LCDR, USN, "Measurements of Currents across the Continental Margin off Point Sur, California, during March 1989," Master's Thesis, March 1993.

Petruncio, E.T., LCDR, USN, "Characterization of Tidal Currents in Monterey Bay from remote and in Situ Measurements," Master's Thesis, December 1993.

Petzrick, E.P., LCDR, USN, "Currents Through the Golden Gate," Master's Thesis, September 1993.

Rugg, S.A., CAPT, USAF, "An Investigation of the Ground-Based High-Resolution Interferometer Sounder (GB-HIS) in a Coastal Marine Environment," Master's Thesis, December 1992.

Skillman, J.B., LT, USN, "ENSO Forced Variations of Sea Surface Temperature and Sea Level Along the West Coast of the United States," Master's Thesis, December 1993.

Spearman, M.G., LCDR, USN, "Water Masses and the Thermohaline Circulation at the Entrance of the Gulf of California," Master's Thesis, September 1993.

DOD KEY TECHNOLOGY AREA: Environmental Effects, Sensors.

KEYWORDS: Ocean Circulation.

**ANALYSIS OF AVHRR SATELLITE IMAGERY FROM THE
SOUTHERN CALIFORNIA BIGHT**

**N. Garfield, Research Assistant Professor
Department of Oceanography**

Sponsor and Funding: Environmental Protection Agency

OBJECTIVE: This project was an Interagency agreement with EPA through the Cooperative Institute for Research in the Integrated Ocean Sciences (CIROS). The objective was to examine a one year data set of AVHRR satellite imagery to determine if these data could be used to monitor upwelling in the Southern California Bight.

SUMMARY: A one year data set of AVHRR imagery for July 1991 to July 1992 was evaluated to determine whether upwelling could be observed at two sites in the Southern California Bight. This work was performed to help EPA designate dredge disposal sites off Los Angeles and San Diego. The data were first evaluated to describe the occurrence of clouds, fog, and other atmospheric contamination. Then, the clear useful imagery were assembled to

allow viewing of the evolution of the surface temperature at these two sites. The final recommendation to EPA was that because of the atmospheric contamination (clouds, haze, and fog) in the Southern California Bight satellite AVHRR imagery was not dependable as a routine tool to monitor coastal upwelling.

OTHER: This work demonstrated how researchers at NPS can work with other government agencies through CIROS. Final report was provided to EPA along with a catalog of AVHRR imagery.

DOD KEY TECHNOLOGY AREA: Environmental Effects.

KEYWORDS: Satellite AVHRR Imagery Processing and Analyses.

ENHANCEMENTS TO DEEP CONVECTION IN THE ARCTIC SYSTEM

R.W. Garwood, Jr., Professor

Department of Oceanography

Sponsor and Funding: National Science Foundation

OBJECTIVE: This is a three-year program of research to explore the roles of turbulent mixing processes that have been neglected in traditional mixed layer modeling applied to the arctic systems of ocean-atmosphere-ice interactions.

SUMMARY: Two kinds of new vertical convection processes that were hypothesized earlier (Garwood, 1992a,b) have been verified numerically by three-dimensional, time-dependent large-eddy simulation of the turbulent fields (Garwood et al., 1993). These complex solutions have been animated, making video movies of the computed velocity, temperature and salinity fields. A new parameterization for penetrative convection that conserves entropy has been demonstrated (Garwood and Isakari, 1993). Synthetic aperture radar (SAR) imagery of the Greenland Sea during winter has been compared with numerical solutions of the surface for a field of convective plumes, and strong similarities were discovered (Carsey and Garwood, 1993), suggesting a role for remote sensing as a tool to diagnose ocean convection.

PUBLICATIONS: Carsey, F.D. and Garwood, R.W., Jr., "Identification of Modeled Ocean Plumes in Greenland Gyre ERS-1 SAR data," Geophysical Research Letters, Vol. 20, pp. 2207-2210, 1993.

Garwood, R.W., Jr., "Missing Physics for Deep Convection?" Arctic System Science Ocean-Atmosphere-Ice Interactions Modeling Workshop, Pacific Grove, CA, Report No. 1, pp. 49-54, 1992.

Garwood, R.W., Jr., "Oceanic Convective Instabilities Hypothesized," ARCSS-OAII Newsletter, Vol. 2, pp. 4-5.

Garwood, R.W., Jr., Isakari, S. and Gallacher, P.C., "Thermobaric Convection, The Role of the Polar Oceans in Shaping the Global Environment," Nansen Centennial Symposium volume, American Geophysical Union Monograph, O. Johannessen, R. Muench, and J. Overland, eds., in press, p. 22, 1993.

Garwood, R.W., Jr. and Guest, A.B., "Greenland Sea Convection Instabilities," WMO Report, in press, 1993.

CONFERENCE PRESENTATIONS: Garwood, R.W., Jr., "Parcel and Layer Instability Convection," Nansen Centennial Symposium, Bergen-Solstrand, Norway, 21-25 June 1993.

Garwood, R.W., Jr. and Isakari, S., "Entropy Conserving Deep Convection in the Weddell Sea," in Proceedings of the Fourth International Conference on Southern Hemisphere Meteorology and Oceanography, Hobart, pp. 503-504, 29 March - 2 April 1993.

Isakari, S.M. and Garwood, Jr. R.W., "Deep Free Convection in the Greenland and Mediterranean Seas," in Proceedings of the Third Scientific Meeting of The Oceanography Society, Seattle, p. 184, 13-16 April 1993.

Garwood, R.W., Jr., "Mixed Layer Dynamics important for Ocean General Circulation Models," Invited speaker

for World Ocean Circulation
Experiment Meeting, Nanaimo,
Vancouver, British Columbia, 13-15
September 1993.

Garwood, R.W., Jr., "Greenland Sea
Convection Instabilities," Invited
speaker at Workshop on Sea-Ice
Modeling, Arctic Climate System Study
Group, World Climate Research Pro-

gram, Hamburg, 13-15 December
1993.

DOD KEY TECHNOLOGY AREA: Environ-
mental Effects, Design Automation.

KEYWORDS: Oceanic Convection, Air-
sea-ice Interactions, Ocean
Simulation.

NUMERICAL EXPERIMENTS IN CONVECTION

R.W. Garwood, Jr., Professor

Department of Oceanography

Sponsor: Office of Naval Research

**Funding: Office of Naval Research and the
Naval Postgraduate School**

OBJECTIVE: This new research is a modeling investigation of the roles of turbulent convection processes that are not resolved and have been neglected and/or inaccurately parameterized in primitive equation models for ocean circulation. We propose to contrast Large-Eddy Simulation (LES) of oceanic deep convection in the Mediterranean with the polar seas. We will include the thermobaric enhancement in models for penetrative convection by parcel instability and entrainment. With the LES as a guide, we intend to develop a fundamentally different (entropy conserving) parameterization for sub-grid scale deep convection in OGCM's.

SUMMARY: Convection in the Mediterranean Sea has been compared with convection in the polar seas, both the Weddell Sea and the Greenland Sea. Rotation is found to influence the planetary boundary layer convection in both polar-sea and Mediterranean sea cases, with Rossby numbers of order unity for surface features that resemble Rayleigh-Benard cells. These cells may be detectible by satellite remote sensing (Carsey and Garwood, 1993).

Inclusion of mixed layer dynamics and convection into oceanic general circulation models has been tested in the Pacific basin (Weddell, 1993), and parameterizations for convection have been developed that may be appropriate for the Mediterranean and polar seas (Garwood and Isakari, 1993). The mean states of the model basin, both dynamic and thermo-

dynamic, are altered by the diurnal "breathing" in the surface buoyancy flux (Guest and Garwood, 1993).

PUBLICATIONS: Carsey, F.D. and Garwood, R.W., Jr., "Identification of Modeled Ocean Plumes in Greenland Gyre ERS-1 SAR data," Geophysical Research Letters, Vol. 20, pp. 2207-2210, 1993.

Garwood, R.W., Jr., Isakari, S., and Gallacher, P.C., "Thermobaric convection, The Role of the Polar Oceans in Shaping the Global Environment," Nansen Centennial Symposium Volume, American Geophysical Union Monograph, O. Johannessen, R. Muench, and J. Overland, eds., in press, p. 22, 1993.

CONFERENCE PRESENTATIONS: Garwood, R.W. and Isakari, S.M., "Entropy Conserving Deep Convection in the Weddell Sea," in Proceedings of the Fourth International Conference on Southern Hemisphere Meteorology and Oceanography, Hobart, pp. 503-504, 29 March - 2 April 1993.

Isakari, S.M. and Garwood, R.W., Jr., "Deep Free Convection in the Greenland and Mediterranean Seas," in Proceedings of the Third Scientific Meeting of The Oceanography Society, Seattle, WA, p. 184, 13-16 April 1993.

Garwood, R.W., Jr., "Mixed Layer Dynamics Important for Ocean General Circulation Models," Invited speaker for World Ocean Circulation

Experiment Meeting, Nanaimo, Vancouver, British Columbia, 13-15 September 1993.

Garwood, R.W., Jr., "Greenland Sea Convection Instabilities," Invited speaker at Workshop on Sea-Ice Modeling, Arctic Climate System Study Group, World Climate Research Program, Hamburg, 13-15 December 1993.

Guest, A.B. and Garwood, R.W., Jr., "Diurnal breathing of the Equatorial Ocean," in Proceedings of the Third Scientific Meeting of The Oceanography Society, Seattle, WA, p. 105, 13-16 April 1993.

THESES DIRECTED: Weddle, Charles A., "The Effect of Westerly Wind Bursts on a Tropical Ocean General Circulation Model," Master's Thesis, 1993.

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DOD KEY TECHNOLOGY AREA: Environmental Effects, Design Automation.

KEYWORDS: Air-sea Interactions, Ocean Turbulence, Large-eddy Simulation.

BOTTOM PRESSURE FLUCTUATIONS ON THE SHELF
INDUCED BY SURFACE WAVES

T.H.C. Herbers, Assistant Professor
Department of Oceanography

R.T. Guza, Co-Investigator, Scripps Institution of Oceanography
Sponsor and Funding: Office of Naval Research

OBJECTIVE: The main objective of this continuing project is to determine the mechanisms by which nearshore infragravity waves are generated.

SUMMARY: Infragravity waves with periods of nominally 0.5-5 minutes are believed to cause changes in beach morphology and drive seiche motions in small harbors. Although the generation of infragravity waves has been linked to shoaling wind waves, the precise mechanisms are not understood. Observations in depths between 8-204 m, near Atlantic and Pacific coasts, were used to show that infragravity waves are a mix of forced waves, locally excited by nonlinear wave-wave interactions, and free waves generated at nearby shores. Although free waves usually dominated the infragravity band, forced wave contributions were significant with large amplitude swells and in very shallow water. Observed forced wave energy levels were shown to be accurately predicted by second-order nonlinear theory. A geometrical optics-based model was developed for the generation and propagation of free infragravity waves. Model predictions are in good agreement with the observations. Free infragravity energy levels are sensitive to the geographic surroundings. Comparisons of observations made on different shelves, suggest that more infragravity energy is generated on broad, sandy beaches than on rocky, cliffed coasts.

PUBLICATIONS: Elgar, S., Herbers, T.H.C., Okihiro, M., Oltman-Shay, J., and Guza, R.T., "Observations of Infragravity Waves," Journal of Geophysical Research, Vol. 97, No. C10, pp. 15573-15577, 1992.

Herbers, T.H.C., Lowe, R.L., and Guza, R.T., "Field Observations of Orbital Velocities and Pressure in Weakly Nonlinear Surface Gravity Waves," Journal of Fluid Mechanics, Vol. 245, pp. 413-435, 1992.

Herbers, T.H.C. and Guza, R.T., "Comment on 'Velocity Observations above a Rippled Bed using Laser Doppler Velocimetry'" by Y. C. Agrawal and D. G. Aubrey, Journal of Geophysical Research, Vol. 98, No. C11, pp. 20331-20333, 1993.

Herbers, T.H.C., Elgar, S., and Guza, R.T., "Infragravity-Frequency (0.005-0.05 Hz) Motions on the Shelf, Part I: Forced waves," Journal of Physical Oceanography, in press.

CONFERENCE PRESENTATIONS: Herbers, T.H.C., Elgar, S., Guza, R.T., and O'Reilly, W.C., "Infragravity-Frequency (0.005-0.05 Hz) Motions on the Shelf," in Proceedings of the Twenty-third International Conference on Coastal Engineering, Venice, Italy, 4-9 October 1992, Billy L. Edge, ed., American Society of Civil Engineers, Chapter 63, pp. 846-859, 1993.

Herbers, T.H.C., Guza, R.T., and Elgar, S., "Infragravity Waves, Part 1: Sources," American Geophysical

Union Fall Meeting, San Francisco, CA, December 1992.

Guza, R.T., Herbers, T.H.C., O'Reilly, W.C., and Elgar, S., "Infragravity Waves, Part 2: Shelf-Wide Variability," American Geophysical Union Fall Meeting, San Francisco, CA, December 1992.

OTHER: Herbers, T.H.C., Elgar, S., Guza, R.T., and O'Reilly, W.C., "Infragravity-Frequency (0.005-0.05 Hz) Motions on the Shelf, Part II: Free Waves," submitted for publica-

tion in the Journal of Physical Oceanography.

DOD KEY TECHNOLOGY AREA:
Environmental Effects.

KEYWORDS: Ocean Surface Waves,
Continental Shelf, Nearshore
Processes.

NONLINEAR INTERACTIONS IN OCEAN SURFACE WAVES

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Department of Oceanography

S. Elgar, Co-Investigator, Washington State University

R.T. Guza, Co-Investigator, Scripps Institution of Oceanography

Sponsor and Funding: Office of Naval Research

OBJECTIVE: The main objective of this continuing project is to evaluate the importance of nonlinear interactions in naturally occurring ocean surface waves.

SUMMARY: Although sophisticated nonlinear theories for ocean surface waves were developed more than 30 years ago, a detailed verification with field observations has not been reported. In this continuing project extensive ocean wave data sets are compared to nonlinear theory predictions. The generation of weakly attenuated secondary pressure fluctuations in the ocean (an important source of sea floor microseisms) by nonlinear interactions between two wind waves traveling in opposing directions was verified using data from an extensive array of pressure sensors deployed in 13 m depth on the North Carolina shelf. Dramatic increases in pressure energy at double wind-wave frequencies (0.3-0.7 Hz), observed after a sudden large shift in wind direction generated directionally opposing waves, were shown to be in good agreement with second-order nonlinear theory predictions. At about three times the frequency of the dominant wind waves, tertiary waves forced by nonlinear interac-

tions between three wind-wave components are important. Trispectral analysis of data collected during a severe nor'easter (the significant wave height was about 5 m) indicates significant tertiary wave contributions to the bottom pressure field.

PUBLICATIONS: Elgar, S., Herbers, T.H.C., and Guza, R.T., "Reflection of Ocean Surface Gravity Waves from a Natural Beach," Journal of Physical Oceanography, in press.

Herbers, T.H.C. and Guza, R.T., "Nonlinear Wave Interactions and High-Frequency Sea Floor Pressure," Journal of Geophysical Research, in press.

OTHER: Elgar, S., Herbers, T.H.C., Chandran, V., and Guza, R.T., "Observations of Nonlinear Ocean Surface Gravity Waves," submitted for publication in the Journal of Fluid Mechanics.

DOD KEY TECHNOLOGY AREA: Environmental Effects.

KEYWORDS: Ocean Surface Waves, Nonlinear Interactions, Sea Floor Pressure.

COASTAL ACOUSTIC TOMOGRAPHIC DATA ASSIMILATION

L.N. Ly, Research Associate Professor

C.-S. Chiu, Associate Professor

Department of Oceanography

Sponsor and Funding: Office of Naval Research (ONR) under
the Navy Ocean Modeling and Prediction Program (NOMP)

OBJECTIVE: The goal of this two-year (FY94-FY95) project was to investigate nowcast/forecast capability of a state-of-the-art primitive equations coastal ocean circulation model using coastal acoustic tomographic data and data assimilation technique of the direct insertion and modified Kalman filter.

SUMMARY: In the first year of the project we focus on application of the direct insertion technique. An application of the modified Kalman filter is the objective of the second year.

A direct insertion scheme for assimilating coastal acoustic tomographic (CAT) vertical temperature section into a multilevel, coastal primitive equation model for the Gulf of Sirte (Lybia) is investigated using numerical experiments. A coastal ocean model was developed for the Mediterranean (MED) Sea at NPS based on the latest version (1992) of Princeton Ocean Model (POM) for the Gulf Stream region (Mellor and Ezer, 1992). Although the model was developed for whole MED, only a model sub-domain covering the Gulf of Sirte was used in the study. The model has realistic coastlines and bottom topography, and coastal-following, curvilinear, nearly orthogonal, horizontal coordinate system with a resolution of about 10 by 10 \$km\$. The model grid was designed by using a grid generation/focusing technique. The model has complete thermodynamics, second order turbulence

closure, and 16 bottom-following (sigma) vertical levels.

Our results strongly indicate that the coast model and the direct insertion scheme for CAT slices work well together. The CAT slices spread information out in nearly all direction in the Gulf Sirte. The inserted data act as an initial convergence maker which forces the model to "loss" memory of the initial state and gradually converge to the "true ocean". The global rms error of the nowcast temperature fields in the considered sub-domain in an experiment involving five CAT sections decreases by about 50 percents after 30 days and 66 percents after 60 days of data assimilation. The temperatures at the mixed-layer level converge more rapidly to the "true temperatures" in comparison to the surface-level temperatures. All the CAT slices have almost the same effectiveness in improving the nowcast fields regardless of their horizontal orientations. Our study shows that convergence is not linearly proportional to the number of CAT slices assimilated. The study confirms that the internal forcing provided by vertical slices derived by CAT is not localized in physical space. They induce immediate correlation between the fully nonlinear primitive equation (PE) model and the CAT data. Our study also confirms that the developed model fully thermodynamical PE model has a good nowcast/forecast capability in a coastal environment.

OTHER: Ly, L.N. and Chiu, C.-S., "Coastal Acoustic Tomography Data Constraints Applied to a Coastal Ocean Circulation Model," NPS Technical Report, submitted for publication, March 1994.

Ly, L.N. and Chiu, C.-S., "A Direct Insertion Assimilation of Coastal Acoustic Tomographic Data into a Coastal Ocean Model for the Gulf of Sirte," A journal paper in preparation; completion is expected mid June 1994.

DOD KEY TECHNOLOGY AREA:
Environmental Effects, Software, Human-System Interfaces.

KEYWORDS: Data Assimilation, Acoustic Tomography, Direct Insertion Assimilation, Coastal Ocean Modeling, Mediterranean Sea, Gulf of Lybia.

**APPLICATION OF GRID GENERATION TECHNIQUE TO THE
COASTAL OCEAN MODELING**

**L.N. Ly, Research Associate Professor
Department of Oceanography
Dr. Phu Luong
Naval Oceanographic Organization (NAVOCEANO),
Stennis Space Center, MS 39529
Sponsor and Funding: NAVOCEANO**

OBJECTIVE: Bring a grid generation technique to the coastal ocean modeling to improve numerical solution and better handle complex coastlines, bathymetry and open boundary conditions by using nearly orthogonal curvilinear horizontal grid system.

SUMMARY: This is a new direction in Coastal Ocean Modeling which brings a grid generation technique of Computation Fluid Dynamics to improve numerical solutions of coastal ocean model. The numerical solution of an ocean circulation model for a region is strongly dependent on the grid used. A grid that is not well suited can lead to unsatisfactory results, including model instability and lack of convergence.

Traditionally, rectangular grids have been most commonly used for their simplicity. However, these grids may

not be well suited to some coastal regions, especially those with complex coastlines and bathymetry

such as the Mediterranean (MED). In many cases open boundary conditions are poorly treated with rectangular grids even at a very high resolution.

A state-of-the-art model for MED is developed at NPS based on the Princeton Circulation Model (PCM) for the Gulf Stream (Mellor and Ezer, 1991). The MED model has 16 vertical levels, free surface dynamics, a second order turbulence closure, and realistic coastlines and bathymetry. The MED model was coupled with nearly orthogonal curvilinear grids designed by using the EAGLEview software package developed by Mississippi State University. The EAGLEview implements a grid generation technique by using elliptic, hyperbolic, and algebraic generation

system. The study of sensitivity of the model numerical solutions to grids was performed. It was found that MED numerical solutions are very sensitive to grid used. A poorly suited grid can not only lead to poor accuracy of the numerical solution, but also can give a totally different interpretation of the physics. With the same number of 15691 grid points, the rectangular grids has only 35 percents of "useful" (inside MED) grid point (20 by 20 \$km\$ resolution), while our nearly orthogonal curvilinear grids have 60 percents "useful" grid points with practical average resolutions of about 12 by 12 \$km\$. The grid generation technique can replace the nesting technique which much more complicated in dealing with boundary conditions and costly in computations.

New proposals with NAVOCEANO on "Model-Data Comparison for MED" and "South China Sea Modeling" are generated based on our successes in MED modeling.

PUBLICATIONS: Ly, L.N. and Kantha, H.L., "A Numerical Study of the Nonlinear Interaction of Hurricane Camille with the Gulf of Mexico Loop Current," Oceanologica Acta, Vol. 16, No. 4, pp. 341-348, 1993.

OTHER: Ly, L.N., Luong P., Chiu, C.-S., Ezer T., and Mellor, G.L., "Numerical Modeling for the Mediterranean Sea Using the Grid Generation Technique." A journal paper is in preparation. Completion is expected mid August 1994.

CONFERENCE PRESENTATION: Ly, L.N., Luong P., and Chiu, C.-S., "Application of the Grid Generation Technique in Coastal Ocean Modeling for the Mediterranean Sea," EOS, Transactions, American Geophysical Union, Vol. 74, p. 325, 1993.

DOD KEY TECHNOLOGY AREA: Design Automation, Computers, Environmental Effects.

KEYWORDS: Grid Generation Technique, Curvilinear Grids, Coastal Modeling, Numerical Modeling, Mediterranean Sea.

AIR-SEA-WAVE INTERACTION MODELING

L.N. Ly, Research Associate Professor

Department of Oceanography

Sponsor and Funding: Office of Naval Research

OBJECTIVE: This is a new direction in air-sea interaction which I have developed for years of my scientific research activities. The study of the air-sea-wave interaction is one of the most important problems of both atmospheric and oceanic physics. This problem is very important not only in theoretical studies of the mechanism of energy transfer in an air-sea-wave system, but also in parameterization of the atmospheric and oceanic boundary-layer processes taking into account surface waves in ocean circulation models and atmospheric climate models.

The transport of momentum, heat, humidity and salt occurs across the air-sea interface with the interaction of the ocean surface waves. The character of this transport is regulated by the turbulence of the atmospheric and oceanic boundary layers. The objective of this research is to develop mathematical model based on atmospheric and oceanic boundary layer physics with taking into account ocean surface waves to study air-sea-wave interaction system.

SUMMARY: A numerical model of air-sea-wave interaction is developed using k - ϵ turbulence scheme. The model is based on a set of equations for (1) momentum, (2) turbulent kinetic energy (TKE), (3) energy-dissipation (ϵ), (4) turbulent exchange coefficient (TEC), expressed in terms of TKE and ϵ , and (5) stratification in the atmosphere and ocean. These equations are written in the same form for both the atmosphere and ocean. The energy dissipation

(ϵ) equations for the air-sea interface are solved analytically to obtain boundary conditions for the ϵ at the interface. Benilov's roughness length, which takes surface wave effects into account for a broad scope of wave ages, is used as an approximation for roughness length at the upper bound of the wave layer. The roughness length of the model is an internal parameter of the air-sea-wave system.

Numerical experiments were carried out with variety of wave heights and wave ages to study the role of surface waves in the air-sea-wave system. The numerical simulation results were compared with available observed data on aerodynamical drag coefficient, friction velocity, roughness length and other.

PUBLICATIONS: Ly, L.N., "Effect of the Angle between Wind Stress and Wind Velocity Vectors of the Aerodynamic Drag Coefficient at the Air-Sea Interface," Journal of Physical Oceanography, Vol. 23, No. 1, pp. 159-163, 1993.

Ly, L.N. and Tackle, E.S., "A Numerical Study of the Influence of the Air Temperature-Inversion Layer and Seawater Density-Jump Layer on the Structure of Atmospheric and Oceanic Boundary Layers," Boundary Layer Meteorology, Vol. 67, No. 4, 1993.

OTHER: Ly, L.N., "A Numerical Model for Studying Air-Sea-Wave Interaction Using the k - ϵ Turbulence Scheme," A journal paper in preparation; completion is expected mid July 1994.

Ly, L.N. and Chalikov, D., "A Theoretical Air-Wave Interaction Model Using the Wave Boundary Layer Theory," NPS Technical Report in preparation; completion is expected mid October 1994.

Ly, L.N. and Chiu, C.-S., "A Numerical Model of Air-Sea-Wave Interaction," Transactions, American Geophysical Union, Vol. 75, p. 135.

DOD KEY TECHNOLOGY AREA:
Environmental Effects, Design Automation.

KEYWORDS: Air-Sea-Wave Interaction, Couple Modeling, Air/Sea Turbulence, Air/Sea Boundary Layers.

**LARGE-SCALE MEAN CONVERGENCE IN THE MIXED LAYER OF THE CANARY
BASIN AS DETERMINED FROM LAGRANGIAN DRIFTERS**

J.D. Paduan, Assistant Professor

Department of Oceanography

Sponsor and Funding: Office of Naval Research

OBJECTIVE: The objective of this project is to obtain statistically reliable estimates of the mean surface currents and temperatures in the Subduction region of the northeast Atlantic Ocean and to use this information, gathered over years, to describe the mean large-scale horizontal convergence near the surface (~15 m). We hope to be able to expose the relative importance of this large-scale frontal convergence as compared with more localized observations and to compare observed convergence with Ekman convergence estimates in order to partition it into wind-driven and non-wind-driven components.

SUMMARY: The approach being used is to make direct measurements of surface currents and temperatures using satellite-tracked Lagrangian drifters. The deployment pattern that is being used was designed to assess the importance of the semi-permanent oceanic front, which occurs south of the Azores Islands, in the north-to-south convergence over the larger Subduction region. Data from 34 drifters has been collected during the first two years. An additional 36 instruments were deployed in this year.

Velocity statistics have been computed for the first two years of drifter trajectories by latitude and season. Although no seasonal patterns were observed when data from the whole region was combined, strong regional patterns were observed when data was analyzed by latitude. In particular, the region including the Azores front had significantly larger velocities, eddy kinetic energies,

and diffusivities than did the ocean regions north or south of the frontal region. Attempts to compute zonally averaged current as a function of latitude have been unsuccessful so far because diffusion bias away from the region of drifter deployments was comparable to the zonally averaged velocities. This result provided important guidance and warnings to future Lagrangian-based experiments as well as the analysis of additional data from this experiment. Drifter observations must be randomly-spaced about the area of interest, particularly in regions of high eddy kinetic energy.

The final drifter deployments in this project were conducted in conjunction with the French-sponsored SEMAPHORE Experiment, which covered the region with additional surface drifters, subsurface floats, and extensive ship-based measurements.

CONFERENCE PRESENTATION: Paduan, J.D., "Drifter-Derived Velocity Statistics in the Canary Basin," 6th Meeting, SVP Planning Committee, Honolulu, HI, 28-30 September 1993.

THESIS DIRECTED: Giannetti, P., LCDR, Italian Navy, "The Velocity Field in the Northeast Atlantic from Satellite-Tracked Drifting Buoys," Master's Thesis, September 1993.

OTHER: The investigator is coordinating this research and its continuation with French scientists making follow-on measurements in the same ocean region.

DOD KEY TECHNOLOGY AREA: Other.

KEYWORDS: Lagrangian Measurements,
Air-sea Interaction, Ocean Eddies,
Currents.

**LAGRANGIAN MEASUREMENTS OF EDDY CHARACTERISTICS IN THE
CALIFORNIA CURRENT**

J.D. Paduan, Assistant Professor

Department of Oceanography

**Sponsor and Funding: Office of Naval Research and the
Naval Postgraduate School**

OBJECTIVE: The objectives of this program are to describe the mesoscale eddy variability in the California Current System off the west coast of the United States and to relate that variability to narrow jet-like features in the current and to the mean current. The data sets to be collected are position and surface temperature following satellite-tracked surface drifters.

SUMMARY: This program is part of a larger coordinated effort to study the eddy field in an eastern boundary current sponsored by the Office of Naval Research. This past year has seen the major field phase of the experiment take place. Through quarterly deployments, 28 surface drifters were placed along an offshore line at 39.5 degrees north latitude (39.5N). The first instruments were placed at 125 degrees west longitude (125W) with approximately 40 km between subsequent deployment sites. Trajectories from these instruments are providing statistics about the mesoscale eddy field of the California Current as a function of season. By November, half of these instruments had traveled south of 34N and one quarter of them had traveled west of 136W.

The second phase of the experiment involves intensive study of a single

eddy to expose its flow structure and its growth or decay rate. Two deployments took place this year. In the first, 13 drifters were placed in a cyclonic eddy in July. Extremely strong wind conditions at that time drove most of the drifters out of the eddy within a few days. In the second deployment, 24 drifters were placed within an anticyclonic eddy in September. Drifters mapped out that feature for up to 14 days. The mean translation velocity of the eddy was (-5.1, -2.4) cm/sec (to the southwest). Typical rotation speeds were 10 to 40 cm/sec with speeds increasing away from the eddy center out to a radius of about 40km.

CONFERENCE PRESENTATION: Paduan, J.D. and Cook, M.S., "Drifting Buoy Observations of Eddies in the Eastern Boundary Current," 40th Eastern Pacific Ocean Conference, Stanford Sierra Camp, Fallen Leaf, CA, 21-23 October 1993.

OTHER: The investigator is coordinating the drifting buoy components of this research program with scientists from the Woods Hole Oceanographic Institution. The investigator's primary responsibility is for collection and analysis of data from the intensive eddy deployments.

DOD KEY TECHNOLOGY AREA: Other.

KEYWORDS: Eddies, Currents Lagrangian Measurements, Air-sea Interaction.

**LAGRANGIAN MEASUREMENTS OF SURFACE CURRENTS OFF
THE CALIFORNIA COAST**

**J.D. Paduan, Assistant Professor
Department of Oceanography**

Sponsor and Funding: Naval Postgraduate School

OBJECTIVE: The objective of this program is to expose surface circulation patterns, including potential differences between upwelling and non-upwelling regimes, in and around Monterey Bay. A primary goal is to describe the flow of the upwelling plume offshore of Monterey Bay, including whether or not the plume actually enters the Bay from the north as is hypothesized and how water subsequently circulates within the outer portions of the Bay. Additional goals include the development and testing of a higher-accuracy drifter design for nearshore observations and the calibration and incorporation of remotely-sensed surface currents from HF radar installations around Monterey Bay.

SUMMARY: Under the general goal of studying the surface circulation in Monterey Bay, this project has developed and evaluated two new technologies for nearshore ocean current measurements. The first of these is surface drifters that utilize higher resolution Global Positioning System (GPS) positioning capability and local buoy-to-shore or buoy-to-ship radio data links. A prototype Global Position Local Telemetry (GPLT) drifter was tested in a cruise off the Galapagos Islands in October. In fact, the drifter became the focal point of that iron enrichment experiment when the

primary drifting buoy failed. The GPLT drifter was followed by the research vessel for a week as measurements around the buoy took place. Reception of the radio signal from the water-level buoy to the ship's mast was better than expected as data was telemetered over distances in excess of 30km. Unfortunately, the end of the experiment purposefully took the research vessel away from the GPLT drifter and it moved out of range and was lost. The success of the prototype means, however, that additional GPLT drifters can be constructed from the materials on hand for this project as engineering manpower becomes available.

The second technology issue being addressed under this program is the verification, calibration, and analysis of CODAR-derived surface currents. The ability to measure surface currents remotely using HF radar installations on the shore has been postulated for over twenty years but relatively few field verifications of this technology have taken place. Through the sponsorship of the National Oceanic and Atmospheric Administration (NOAA), three HF radars of the CODAR design have been installed around Monterey Bay. This program has already analyzed a continuous, three-month current record from CODAR and found

that the remotely-sensed currents compare favorably with traditional moored observations for motions with periods greater than a week and for higher frequency tidal and diurnal-period motions. During this year, two additional Master's theses projects were carried out based on CODAR data from September 1992. Strong links between surface currents and the atmospheric sea breeze circulation were established and tidal currents were investigated. The unique spatial information obtained from the radar data showed tidal currents were modified and amplified by the topography of the Monterey Submarine Canyon.

THESES DIRECTED: Foster, M.D., LCDR, USN, "Evolution of Diurnal Surface Winds and Surface Currents for Monterey Bay," Master's Thesis, December 1993.

Petruncio, E.T., LCDR, USN, "Characterization of Tidal Currents in Monterey Bay from Remote and in Situ Measurements," Master's Thesis, December 1993.

OTHER: As part of this project and the follow-on project entitled, "Analysis of Radar-Derived Surface Currents in Monterey Bay from CODAR," sponsored by the Naval Postgraduate School, the investigator is coordinating the testing and use of a larger network of HF radars in the Monterey Bay area. This multi-institutional effort is now being organized as the Monterey Bay HF Radar Consortium.

DOD KEY TECHNOLOGY AREA: Electronic Devices, Environmental Effects.

KEYWORDS: Currents, HF radar, CODAR, Lagrangian Measurements, Tides, Air-sea Interaction.

**CURRENT OBSERVATIONS OVER THE CONTINENTAL SLOPE OFF
POINT SUR, CALIFORNIA**

**S. Ramp, Research Associate Professor
C.A. Collins, Chairman and Professor
Department of Oceanography**

**Sponsor and Funding: Office of Naval Research and the
Naval Postgraduate School**

OBJECTIVE: To provide a long time series of current measurements over the upper slope in an Eastern Boundary Current region.

SUMMARY: The Naval Postgraduate School (NPS) began observations of currents off Pt. Sur in May 1989 and we have been able to maintain a mooring in 800m of water since that time. The mooring was replaced in April 1993. On the Wednesday before Thanksgiving 1993, the mooring was cut above the acoustic releases by a trawler. All equipment (and data) was subsequently recovered and the

mooring was again replaced on February 9, 1994.

The time series is unique. No year appears to be "typical". Although poleward flow dominates, oscillations vary from biweekly to in excess of 200 days. Data from this time series have been used in theses by NPS students Tisch, Seilbeck, and Hicks.

DOD KEY TECHNOLOGY AREA: Environmental Effects.

KEYWORDS: Continental Slope, Pt. Sur.

SATELLITE OCEAN COLOR IN THE LITTORAL ZONE

A.J. Semtner, Jr., Professor

N. Garfield, Assistant Professor

Department of Oceanography

Sponsor: NAVOCEANO

Funding: Naval Postgraduate School

OBJECTIVE: The purpose is to obtain ocean color data from the soon to be launched SeaWiFS sensor in order that these data will be available in the IDEA Laboratory for both teaching and research purposes. The shift in naval strategy toward a force capable of operating in the near shore region demands improved surveillance capabilities. Satellite data from the visible spectrum may prove to be an important tool in developing these capabilities. The work carried out through this proposal will provide NPS students with opportunity to evaluate the potential usefulness of ocean color data and make recommendations concerning the incorporation into TESS(3) capabilities.

SUMMARY: The SMQ/11 satellite receiving antenna installed on the roof of Root Hall will allow reception of SeaWiFS ocean color data after the satellite is launched in the summer of 1994. The work carried out here is to ensure the capture and processing of the SeaWiFS data.

DOD KEY TECHNOLOGY AREA: Sensors, Environmental Effects.

KEYWORDS: Ocean Color, Littoral Zone.

**SCIENTIFIC DEVELOPMENT OF A MASSIVELY PARALLEL
OCEAN CLIMATE MODEL**

**A.J. Semtner, Jr., Professor
Department of Oceanography**

Sponsor: National Science Foundation

**Funding: U.S. Department of Energy
(for the CHAMMP Program on Climate Research)**

OBJECTIVE: The purpose of this project is to transition global ocean prediction models onto massively parallel computers.

SUMMARY: The funded research is moving an existing global eddy-resolving ocean model onto massively parallel computers, for climate studies related to CHAMMP. To guide the proper physical development of a comprehensive model, scientific study in three areas is being undertaken: (i) investigation of the physics of ocean heat transport; (ii) inclusion of near-surface oceanic processes relevant to climate; and (iii) examination of resolution requirements for ocean climate modeling. The final and most important aspect of the research will be the demonstration of feasibility and scalability of a climatically-sound global ocean model for per-

forming multi-century integrations at a grid spacing as fine as 1/8 degree on massively parallel machines.

PUBLICATION: Semtner, A.J., "Very High-Resolution Estimates of Global Ocean Circulation, suitable for Carbon Cycle Modeling," in Proceedings of the Snowmass Global Change Institute on the Global Carbon Cycle. Office of Inter-disciplinary Research, Boulder, CO, in press.

THESIS DIRECTED: O'Carroll, Rosemarie, LT, USN, "An Analysis of Eddy-Resolving Global Ocean models in the Southern Ocean," Master's Thesis, September 1993.

DOD KEY TECHNOLOGY AREA: Computers.

KEYWORDS: Ocean Modeling.

**DEVELOPMENT OF A GLOBAL EDDY RESOLVING THERMODYNAMIC
OCEAN MODEL**

**A.J. Semtner, Professor
Department of Oceanography
Sponsor: National Science Foundation
Funding: National Science Foundation/
Physical Oceanography Program**

OBJECTIVE: The purpose of this project is to develop global ocean prediction models.

SUMMARY: Research is being funded to implement and test a free-surface formulation for the global eddy-resolving ocean model, in order to improve certain physical and numerical aspects of the calculation. Since very complicated geometries can be handled, the global ocean is being configured with fully realistic geometry, including the Arctic Basin and all marginal seas, at both 1/2 and 1/4 degree gridsizes. Prognostic integrations of the improved model are included, with simulations of 20 years and 5.0 years at the two gridsizes, respectively.

PUBLICATIONS: Semtner, A.J. and

R.M. Chervin, "Including Eddies in Global Ocean Models," EOS, Transactions, American Geophysical Union, Vol. 74, No. 5, p. 59, 1993.

McCann, M.P., Semtner, A.J., and Chervin, R.M., "Transports and Budgets of Volume, Heat, and Salt from a Global Eddy-Resolving Ocean Model," Climate Dynamics, in press.

THESIS DIRECTED: Marble, Douglas, LT, USN, "A Model Analysis of Potential Vorticity on Isopycnal Surfaces for the Global Ocean," Master's Thesis, September 1993.

DOD KEY TECHNOLOGY AREA: Computers.

KEYWORDS: Ocean Modeling.

THE TURBULENT STRUCTURE OF EVOLVING ARCTIC LEADS

T.P. Stanton, Associate Research Professor

Department of Oceanography

Sponsor: Office of Naval Research, Small Scale PO

Funding: Cost Share ONR and the Naval Postgraduate School

OBJECTIVE: The goal of this research program is to define the dynamics controlling turbulent fluxes in the ocean mixed layer as arctic leads refreeze.

SUMMARY: A 4 week field program during March and April 1992 provided an opportunity to measure continuous profiles of microstructure-resolving temperature, salinity, velocity shear and acoustic backscatter at the down-current side of four fresh arctic leads. Simultaneous quantitative video timelapse records of the lead surface structure were recorded at each site.

Over 1000 continuous timeseries profiles were recorded with our automated profiling system providing a unique record of the mean and turbulent structure over a range of lead sizes and forcing conditions.

The large data processing task on the 80 Gigabytes of raw data has been completed, and analyses of the dissipation and very high resolution T/S profiles is in progress. A paper describing the unexpected reversal of mixed layer heat fluxes by solar radiation has been submitted. Two further collaborative papers describ-

ing the changes in turbulence characteristics of the ocean boundary layer and their relationship to ice formation and deformation events are currently being written for submission to the JGR leads and polynias special issue. CTD timeseries and surface condition data have been contributed to the LEADEx database.

PUBLICATION: Stanton, T.P., The Leadex Group, "The LeadEx Experiment" EOS, Vol. 74, p. 35, August 1993.

CONFERENCE PRESENTATIONS: Stanton, T.P., "Structure of Turbulent Boundary Layers Under Refreezing Arctic Leads," TOS 3rd Scientific Meeting, Abstract 2-GCH-120, Seattle, WA, 13-16 April 1993.

Stanton, T.P., "Observations of Shear, Dissipation and Stress Below Oceanic Wind Waves Using Coherent Acoustic Profilers," Symposium on The Air-Sea Interface, Marseilles, France, 24-30 June 1993.

DOD KEY TECHNOLOGY AREA: Environmental Effects.

KEYWORDS: Arctic Leads, Ocean Turbulence, Mixed Layer Dynamics.

COHERENT ACOUSTIC SEDIMENT FLUX PROBE

T.P. Stanton, Associate Research Professor

E.B. Thornton, Professor

Department of Oceanography

Sponsor: U.S. Army Engineer Waterways Experiment Station

Funding: U.S. Army Corps of Engineers

OBJECTIVE: The goal of this research program is to develop a 3 component sediment flux probe with high temporal and spatial resolution for use in wave/sediment transport studies. The simultaneous measurement of the three-component velocity vector, dual-frequency backscatter level, and local beam attenuation will provide a unique capability in the estimation of sediment load and fluxes.

SUMMARY: The CASP probe has been completed and put through preliminary ocean field tests during FY93. The CASP instrument package consists of 3, 5.2MHz acoustic transceivers, one 1.3 MHz transceiver, sequence controllers, tilt sensors, 3-axis accelerometer, precession depth sensor and high speed digitizer and data transmission system. The 1.4 Mbaud data stream from the instrument has been designed to be compatible with our existing VCR-based recording system, DSP-based preprocessors, back end data processing, and data visualization tools.

A controlled concentration test tank

and calibration facility has been completed during FY93, and the backscatter calibration and mass inversion problem is a the topic of current thesis work. A report detailing the operating principals and implementation of the CASP probe has been completed and submitted to the sponsors. A paper and patent describing the unique capabilities of this instrument is being prepared.

PUBLICATION: Stanton, T.P., "The Coherent Acoustic Sediment Flux Probe (CASP)," USAE Water Ways Experiment Station, Army Corps of Engineers Report for contract number W81EW-3-CD30, September 1993.

THESIS DIRECTED: Anderson, W., LCDR, USN, "Acoustic Backscatter Mass Concentration Techniques for a Sediment Flux probe," in progress.

DOD KEY TECHNOLOGY AREA: Environmental Effects.

KEYWORDS: Sediment Transport, Acoustic Doppler, Turbulent Fluxes.

NEARSHORE WAVE PROCESSES

E.B. Thornton, Professor

T.P. Stanton, Associate Research Professor

Department of Oceanography

Sponsor and Funding: Office of Naval Research

OBJECTIVE: The long-term goals are to predict the wave-induced three-dimensional velocity field and induced sediment transport over arbitrary bathymetry in the near shore.

SUMMARY: Abreu, Larraza and Thornton (1992) developed a shallow water, nonlinear spectral wave transformation model based on the radiative transport equations describing the change in wave action balanced by the nonlinear resonant triad interactions described by a collision integral; good agreement is obtained with the high-resolution frequency-directional wave measurements.

Dodd, Oltman-Shay and Thornton (1992) verified the theoretical model for shear instability of longshore currents by Bowen and Holman (1990) using SUPERDUCK field measurements. The longshore current model of Thornton and Whitford (1993) was used to interpolate the SUPERDUCK velocity profiles. The shear instability model was extended to include the effects of dissipation in the form of bottom friction. Dodd and Thornton (1990) had earlier shown that a necessary condition for the growth of the instability is that there be a transfer of momentum of the mean flow to the cross-shore gradient of the covariance of the horizontal velocity of the perturbed flow, i.e. a cross-shore gradient of the Reynolds' stress due to the shear instability must exist. Church, Thornton, and Oltman-Shay (1993) calibrated this momentum mixing by shear instabilities to show that they can

cause sufficient mixing to explain deficiencies in our present longshore current models.

Thornton and Kim (1993) showed that the variability of longshore currents associated with tidal effects is $O(1)$. Breaking wave heights are modulated by the changing depth of water due to the tide elevation, which in turn modulate the longshore currents inside the surf zone at the tidal frequency. The hypothesis was verified using the DELILAH data.

During the upcoming DUCK94 experiment doppler acoustic, stereo-video and surveying technologies to develop new instrumentation will be implemented to make unique measurements of sediment transport, turbulence, breaking waves and small-scale morphology. Direct measurements will be made of suspended and bedload sediment flux, stress, and dissipation over the vertical, small-scale morphology including ripples and mega-ripples, breaking wave characteristics and the vertical structure of mean currents.

PUBLICATIONS: Abreu, M., Larraza, A., and Thornton, E., "Nonlinear Transformation of Directional Wave Spectra in Shallow Water, Journal of Geophysical Research, Vol. 97, No. C10, pp. 15579-15589, 1992.

Whitford, D.J. and Thornton, E.B., "Comparison of Wind and Wave Forcing of Longshore Currents," Continental Shelf Research, Vol. 13, No. 11, pp. 1205-1218, 1993.

Church, J.C. and Thornton, E.B., "Effects of Breaking Wave Induced Turbulence within a Longshore Current Model," Journal of Coastal Engineering, Vol. 20, pp. 1-28, 1993.

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Church, J.C., Thornton, E.B., and Oltman-Shay, J., "Mixing by Shear Instabilities of the Longshore Current," in Proceedings of the 23rd Coastal Engineering Conference, American Society of Civil Engineers, pp. 3013-3025, 1992.

Dodd, N. and Thornton, E.B., "Longshore Current Instabilities: Growth to Finite Amplitude," in Proceedings of the 23rd Coastal Engineering Conference, American Society of Civil Engineers, pp. 2655-2668, 1992.

CONFERENCE PRESENTATIONS: Thornton, E.B., and Church, J.C., "Modeling Strong Longshore Currents during DELILAH," International Conference on Coastal Engineering, Venice, Italy, 4-10 October 1992.

Church, J.C., Thornton, E.B., and Oltman-Shay, J., "Mixing by Shear Instabilities of the Longshore Current," International Conference on Coastal Engineering, Venice, Italy, 4-10 October 1992.

Kim, C.S. and Thornton, E.B., "Tidal Modulation of Longshore Currents,"

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Dodd, N. and Thornton, E.B., "Longshore Current Instabilities: Growth to Finite Amplitude," International Conference on Coastal Engineering, Venice, Italy, 4-10 October 1992.

Thornton, E.B., (Invited), "Near Shore Process Studies: Past, Present and Future," Portuguese Hydrographic Institute, 13 October 1992.

Humiston, R. and Thornton, E.B., "Cross-shore Transport during DELILAH," Fall Meeting - American Geophysical Union, San Francisco, CA, 7-10 December 1992.

Thornton, E.B. and Church, J.C., "Set-up/Down During DELILAH," Fall Meeting - American Geophysical Union, San Francisco, CA, 7-10 December 1992.

Oltman-Shay, J., Howd, P.A., Holman, R.A., Guza, R.T., and Thornton, E.B., "Evidence of High Mode Infragravity Edge Waves in the Nearshore," Fall Meeting - American Geophysical Union, San Francisco, CA, 7-10 December 1992.

Lippman, T., Holman, R.A., and Thornton, E.B., "Wave Breaking in the Trough of a Natural Sand Bar," Fall Meeting - American Geophysical Union, San Francisco, CA, 7-10 December 1992.

THESES DIRECTED: Humiston, Randall, T., "Cross-Shore Sediment Transport on a Naturally Barred Beach," Master's Thesis, March 1993.

Brookins, A. Henry, "Ocean Wave Height Transformation Model Using Surface Roller Theory," Master's Thesis, June 1993.

Church, John Casey, "Topics in Longshore Currents," Ph.D Dissertation, September 1993.

DOD KEY TECHNOLOGY AREA: Environmental Effects.

KEYWORDS: Nearshore Processes, Surface Waves, Longshore Currents, Surf Zone.

SURF AND NEAR SHORE CURRENT PREDICTION

E.B. Thornton, Professor

Department of Oceanography

Sponsor and Funding: Office of Naval Research

OBJECTIVE: The objective is to predict the evolution of waves across the surf zone and the currents in the nearshore due to waves, wind and tidal influences.

SUMMARY: The surf prediction portion of the TESS 2.2 is based on describing the waves as narrow banded with a single frequency and single direction with randomness described via the probability distribution of wave heights. Predictions require the specification of two dissipation parameters to predict wave transformation and two additional parameters, bed shear stress and turbulent mixing coefficients, to predict longshore currents. The complexities of breaking wave processes within the surf zone require that these coefficients be determined empirically. Field experiments are required for the empirical determination of the coefficients due to scaling problems of laboratory experiments. The model gives reasonable results for near planar beaches, but questionable results on barred beaches. The surf prediction model is being tested and validated utilizing the comprehensive wave and current data on the barred

beach acquired during the DELILAH experiment conducted off the outerbanks of North Carolina. Progress to date includes:

1) The DELILAH experiment data were archived. The data were acquired continuously over a 19 day period at a sampling rate of 8Hz. The data has been archived in terms of wave height, current, mean wave direction, peak period and bathymetry.

2) The wave transformation model was tested to allow specification of dissipation parameters and make the model more robust. The optimal parameters in the wave transformation model describing breaking wave intensity and wave saturation have been determined by least square fits with 74 data sets covering a wide range of wave conditions. These parameters are combined into a single parameter and related to wave steepness and beach slope.

3) The wave transformation model has been rederived to include the effects of a surface roller describing breaking waves and dissipation (Brookins, 1993; Brookins, et al, 1993). The resulting formulation

also has two parameters to be specified, the steepness of the breaking wave face and the wave saturation parameter. The model was run for various cases of near planar (Torrey Pines and Santa Barbara) and barred (DELILAH) beaches. It was found that the model is insensitive to the steepness of the breaker face and moderate to weakly sensitive to wave saturation. Running the new model with the now specified parameters and comparing with data results in a 40% improvement in the rms error over the present TESS model. The average rms error for all runs is less than 5%.

THESIS DIRECTED: Brookins, H., "Wave Transformation Roller Model," Master's Thesis, 1993.

DOD KEY TECHNOLOGY AREA: Environmental Effects.

KEYWORDS: Nearshore Processes, Surface Waves, Longshore Currents, Surf Zone.

WAVE TRANSFORMATION AND REFLECTION FROM THE MONTEREY BREAKWATER

**E.B. Thornton, Professor
Department of Oceanography
Sponsor and Funding: U.S. Army Corps of Engineers,
San Francisco District**

OBJECTIVE: Waves are measured on both sides of the Monterey breakwater using an array of pressure sensors to determine the transmitted and reflected wave energy spectra. Conditions before and after repair of the breakwater are compared to determine the improved characteristics of wave protection by the breakwater.

SUMMARY: A six element array of pressure sensors were installed on the ocean side and a single pressure sensor inside of the Monterey breakwater to determine the reflected and transmitted wave energy spectra. Conditions before and after repair of

the breakwater are being compared to determine the improved characteristics of wave protection by the breakwater. A generalized methodology to determine the spectral reflection characteristics has been derived. This procedure is being tested with a wide variety of wave conditions acquired to examine the robustness of the methodology and the amount of nonlinearity of the transmission processes.

DOD KEY TECHNOLOGY AREA: Environmental Effects.

KEYWORDS: Nearshore Processes, Surface Waves, Breakwater.

**DEPARTMENT
OF
OCEANOGRAPHY**

**1993
Faculty Publications
and Presentations**

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Carsey, F.D. and Garwood, Jr., R.W., "Identification of Modeled Ocean Plumes in Greenland Gyre ERS-1 SAR Data," Geophysical Research Letters, Vol. 20, pp. 2207-2210, 1993.

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Herbers, T.H.C., Elgar, S., Guza, R.T., and O'Reilly, W.C., "Infragravity-Frequency (0.005-0.05 Hz) Motions on the Shelf," in Proceedings of the Twenty-third International Conference on Coastal Engineering, 4-9 October 1992, Venice, Italy, Billy L. Edge. ed., American Society of Civil Engineers, Chap. 63, pp. 846-859, 1993.

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Ly, L.N., Luong, P., and Chiu, C.-S., "Application of Grid Generation Techniques for Coastal Ocean Modeling," Fall AGU Meeting, San Francisco, CA, 1993.

Lynch, J.F., Chiu, C-S., and Miller, J.H., "Forward Modeling for Coastal Acoustic Tomography," International Conference on Theoretical and Computational Acoustics, Mystic, CT, 5-9 July 1993. (Invited)

Thornton, E.B. and Church, J.C., "Modeling Strong Longshore Currents during DELILAH," in Proceedings of the 23rd Coastal Engineering Conference, American Society of Civil Engineers, pp. 2999-3011, 1993.

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Chiu, C.-S., Miller, J.H., and Lynch, J.F., "Inverse Techniques for Coastal Acoustic Tomography," 1993 International Conference on Theoretical and Computational Acoustics, Mystic, CT, 5-9 July 1993.

Chiu, C.-S., Miller, J.H., and Lynch, J.F., "Tomographic Measurements of Frontal Variability in the Barents Sea," Denver ASA Meeting, 4-8 October 1993.

Chiu, C.-S., Lynch, J.F., and Miller, J.H., "Scattering from Frontal Structures, Internal Tides, and Internal Waves during the 1992 Barents Sea Polar Front Experiment," Denver ASA Meeting, 4-8 October 1993.

Chu, P.C., "Intrinsic Thermodynamical Time Scales," Fourth Symposium on Global Change Studies, American Meteorological Society, Anaheim, CA., 17-22 January 1993.

Chu, P.C. and Kuo, Y.H., "South Atlantic Three Dimensional Pseudo-Vorticity Field," Fourth International Conference on Southern Hemisphere Meteorology & Oceanography, Hobart, Australia, 29 March - 2 April 1993.

Chu, P.C., "Three Dimensional Vorticity Field in Atlantic Ocean," The Oceanography Society Meeting, Seattle, WA, 12-17 April 1993.

Chu, P.C., Li, C.C., Ko, D.S., and Mooers, C.N.K., "South China Sea Ocean Prediction System," American Geophysical Union Fall Meetings, San Francisco, CA, 6-10 December 1993.

Chu, P.C., Konstandinidis, S., Jessen, P., and Collins, C.A., "C-Vector Method derived Three Dimensional Circulation in Farallones National Sanctuary," 1993 Fall National Meeting, American Geophysical Union, San Francisco, CA, 6 December 1993.

Church, J.C., Thornton, E.B., and Guza, R.T., "Vertical Profiles of Longshore Currents: Field Observations," Fall Meeting, American Geophysical Union, San Francisco, 6-11 December 1993.

Church, J.C., Thornton, E.B., and Oltman-Shay, J., "Mixing by Shear Instabilities of the Longshore Current," 23rd Coastal Engineering Conference, American Society of Civil Engineers, 1993.

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Garfield N., Rago, T.A., Spearman, M.G., Collins, C.A., Mascarenhas, A., Sanchez-Devora, A., and Navarro-Olache, L., "Hydrographic and Pegasus Observations at the Mouth of the Gulf of California," 1993 Eastern Pacific Oceanography Conference, Stanford Sierra Camp, Fallen Leaf Lake, CA, 1993.

Garwood, R.W., Jr., "Parcel and Layer Instability Convection," Nansen Centennial Symposium, Bergen-Solstrand, Norway, 21-25 June 1993.

Garwood, R.W., Jr., "Mixed Layer Dynamics important for Ocean General Circulation Models," Invited speaker for World Ocean Circulation Experiment Meeting, Nanaimo, Vancouver, British Columbia, 13-15 September 1993.

Garwood, R.W., Jr., "Greenland Sea Convection Instabilities," Invited speaker at Workshop on Sea-Ice Modeling, Arctic Climate System Study Group, World Climate Research Program, Hamburg, 13-15 December 1993.

Garwood, R.W., Jr. and Isakari, S., "Entropy Conserving Deep Convection in the Weddell Sea," Fourth International Conference on Southern Hemisphere Meteorology and Oceanography, 29 March - 2 April 1993.

Guest, A.B. and Garwood, R.W., Jr., "Diurnal 'breathing' of the Equatorial Ocean," Third Scientific Meeting of the Oceanography Society, Seattle, WA, 13-16 April 1993.

Herbers, T.H.C., Elgar, S., and Guza, R.T., "Infragravity Waves," American Geophysical Union Fall Meeting, San Francisco, CA, December 1993.

Isakari, S.M. and Garwood, R.W., Jr., "Deep Free Convection in the Greenland and Mediterranean Seas," Third Scientific Meeting of the Oceanography Society, Seattle, WA, 13-16 April 1993.

Lippmann, T.C., Thornton, E.B., and Herbers, T.H.C., "Observations of Infragravity Wave Pressure and Velocities in the Surf Zone," American Geophysical Union Fall Meeting, San Francisco, CA, December 1993.

Ly, L.N., Luong, P., and Chiu, C.-S., "Application of Grid Generation Techniques for Coastal Ocean Modeling," Fall AGU Meeting, San Francisco, CA, 1993.

Lynch, J.F., Chiu, C.-S., and Miller, J.H., "Forward Modeling for Coastal Acoustic Tomography," International Conference on Theoretical and Computational Acoustics, Mystic, CT, 5-9 July 1993.

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O'Reilly, W.C., Herbers, T.H.C., Guza, R.T., and Seymour, R.J., "A Comparison of Directional Buoy and Fixed Platform Wave Measurements," American Geophysical Union Fall Meeting, San Francisco, CA, December 1993.

Paduan, J.D., "Drifter-Derived Velocity Statistics in the Canary Basin," 6th Meeting of the SVP Planning Committee, Honolulu, HI, September 1993.

Paduan, J.D. and Cook, M.S., "Drifting Buoy Observations of Eddies in the Eastern Boundary Current," 40th Eastern Pacific Ocean Conference, Stanford Sierra Camp, Fallen Leaf, CA, October 1993.

Rischmiller, F.W., Garfield, N., Collins, C.A., and Rago, T.A., "Seasonal Variability of Ocean Currents off Pt. Sur, California from May 1988 to April 1991," 1993 Fall National Meeting, American Geophysical Union, San Francisco, CA, 6 December 1993.

Scott, K.A., Thornton, E.B., and Guza, R.T., "Undertow in the Surfzone," Fall Meeting, American Geophysical Union, San Francisco, CA, 6-11 December 1993.

Semtner, A.J., "Global Ocean Simulations with European-Center Wind Forcing," Science Colloquium of the Model Evaluation Consortium for Climate Assessment, Boulder, CO, 25-26 January 1993.

Semtner, A.J., "Progress in Eddy-Resolving Global Ocean Prediction," Meeting of the U.S. Science Steering Committee of the World Ocean Circulation Experiment, Dallas, Texas, 9-11 February 1993.

Semtner, A.J., "Construction of a 1/4-Degree Global Ocean Model," Science Steering Team Meeting of the Computer Hardware, Advanced Mathematics, Model Physics Program, Monterey, CA, 15-17 March 1993.

Semtner, A.J., "Simulations of the Southern Ocean Circulation from a Global Model," Fourth International Conference on Southern Hemisphere Meteorology and Oceanography, Hobart, Tasmania, 29 March - 2 April 1993.

Semtner, A.J., "The Influence of Polar Ocean Processes on Global Ocean Circulation," Nansen Centennial Symposium of the Role of the Polar Oceans in Climate, Bergen, Norway, 21-25 June 1993.

Semtner, A.J., "High Resolution Global Ocean Simulations, Suitable for Use in Carbon Cycle Modeling," UCAR/OIES Global Change Institute, Snowmass, CO, 19-23 July 1993.

Semtner, A.J., "Progress in Modeling Global Ocean Circulation with 1/4 and 1/6-Degree Grids," Oceanography Departmental Seminar, 1 September 1993; and the Los Alamos National Laboratory Seminar, 8 September 1993.

Semtner, A.J., "Progress in Simulating Global Ocean Circulation with 1/4 and 1/6-Degree Grids," International meeting of the World Ocean Circulation Experiment, Victoria, British Columbia, 13-17 September 1993.

Semtner, A.J., "Eddy-Resolving Modeling of Global Ocean Circulation with 1/4 and 1/6-Degree Grids," Seminar at the National Center for Atmospheric Research, Boulder, CO, 27 September 1993.

Semtner, A.J., "Modeling the Ocean as Part of the Climate System," Dartmouth College seminar, Dartmouth, NH, 18 October 1993.

Semtner, A.J., "High-Resolution Modeling of the Global Ocean Circulation," MIT Seminar, Cambridge, MA, 21 October 1993.

Semtner, A.J., "Global Ocean Models Suitable for Satellite Data Assimilation," Satellite Altimetry and Oceanography Symposium, Toulouse, France, 29 November - 3 December 1993.

Stanton, T.P., "Structure of Turbulent Boundary Layers Under Refreezing Arctic Leads," TOS 3rd Scientific Meeting, Abstract 2-GCH-120, Seattle, WA, 13-16 April 1993.

Stanton, T.P., "Observations of Shear, Dissipation and Stress Below Oceanic Wind Waves Using Coherent Acoustic Profilers," Symposium on The Air-Sea Interface, Marseilles, France, 24-30 June 1993.

Thornton, E.B., "Overview of the DUCK94 Nearshore Experiment," Small-scale Granular Fluids Conference, Amelia Island, FL, 10-14 March 1993.

Thornton, E.B., Humiston, R., and Birkemier, W., "Cross-Shore Sediment Transport on a Naturally Barred Beach," Fall Meeting, American Geophysical Union, San Francisco, CA, 6-11 December 1993.

Thornton, E.B. and Church, J.C., "Modeling Strong Longshore Currents during DELILAH," 23rd Coastal Engineering Conference, American Society of Civil Engineers, 1993.

Wilson, J.H., "Backus-Gilbert Inverse Theory Applied to the Inverse Beamforming Integral Equation," Naval Research Laboratory, WA, 1993.

Wilson, J.H., "Wilson Shallow Water Frequency Dispersion Phenomenon," Naval Air Warfare Center, Warminster, PA, June 1993.

Wilson, J.H., "Tomographic Inverse Beamforming," Annual Fall Meeting of the Acoustical Society of America, Denver, CO, November 1993.

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Chiu, C.S. and Ehret, L.L., "Three-Dimensional Acoustic Mode Propagation through the Gulf Stream," in Coupled Ocean Prediction and Acoustic Propagation Models, Robinson and Lee, eds., American Institute of Physics, 1993.

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Bourke, R. H., Wilson, J.H., and Buck, B.M., "Survey of Acoustic Results for Arctic Shallow Water," NUWC-NPT Technical Document 10,485, August 1993.

Chiu, C-S., "Downslope Modal Energy Conversion," ATOC Occasional Notes, No. 10, 1993.

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Mitchell, R.P. and Batteen, M.L., "A Numerical Study of Seasonal Wind Forcing Effects on the California Current System," NPS Technical Report NPS-OC-93-001, March 1993.

Paquette, R.G. and Bourke, R.H., "The Use of a Submarine-Mounted Conductivity-Temperature-Depth Recorder in the Arctic (U)," NPS Technical Report NPS-OC-93-003, September 1993.

Stanton, T.P., "The Coherent Acoustic Sediment Flux Probe (CASP)," USAE Water Ways Experiment Station, Army Corps of Engineers Report for contract number W81EW7-3-CD30, September 1993.

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Garwood, R.W., Jr., "Oceanic Convective Instabilities Hypothesized," ARCS-CAII Newsletter, Vol. 2, pp. 4-5, 1993.

**DEPARTMENT
OF
OPERATIONS RESEARCH**



**Peter Purdue
Chairman**

DEPARTMENT OF OPERATIONS RESEARCH

The research program in the department of Operations Research seeks to advance the field's state of knowledge in areas important to the Department of Navy, Department of Defense, and military planning. The study of operational problems often involves the structuring and integration of a number of interdisciplinary components, and the result is a very rich collection of applications. In many instances the methodologies developed are of general interest extending well beyond the problems that spawned them. In these cases our researchers will generalize their work and seek broader recognition.

This report contains the research summaries submitted by the department faculty for the calendar year 1992. For the convenience of the reader, a "summary of the summaries" appears in this cover statement. It is organized according to academic content, and the descriptions are largely in terms of the applied problems treated. Authors are identified in parentheses, and upon occasion, names of collaborators outside of our department are also identified. The specific areas currently represented are optimization, stochastic models and simulation, statistics and data analysis, combat modelling and war gaming. Sponsors are not immediately identified, but can be located in the individual summaries.

Tangible output appears in the form of student theses, reports to sponsors, conference presentations, Naval Postgraduate School technical reports, and refereed articles in the open professional literature. The research summaries of department faculty whose efforts involved projects sponsored outside of the department are reported elsewhere. Also, research involving security classified matters are not reported here.

OPTIMIZATION

Research continues into the development of theory and algorithms for the solution of large-scale optimization models; techniques were developed for the automatic exploitation of special structure (Bradley, Brown, Wood). Efficiencies of NATO's international numbering and routing scheme are under study (Kemple, Bailey, Sovereign). Optimization based decision tools are being developed for the analysis of Army base realignment and closure (Dell, Parry, Rosenthal). An optimization model for scheduling Coast Guard assets has been developed (Bailey, Dell, Glazebrook).

PC based computer models have been developed to overview the Army's delayed entry program losses (Milch). A forecast model for the probability that a recruit invalidates his enlistment contract has been formulated (Lawphonpanich, Milch, Whitaker). A tool for realigning the Navy's recruiting station structure has been developed (Hallwachs, Lawphonpanich). The realignment of Army recruiting stations based upon anticipated contracts is under study (Lawphonpanich, Sohn). The optimization of the Army's recruiting advertising budget is under study (Sohn).

New methods have been applied to the problem of optimizing the assignment of frequencies to a direction finding network (Washburn).

STOCHASTIC MODELING AND SIMULATION

The development of models for the aggregation of damage due to weapons salvoes continues (Esary). Initiation of methods to forecast the degradation of aircraft readiness has begun (Gaver, Jacobs). Models of organic cell response to toxins have been proposed (Gaver, Jacobs). Work continues on environmental shapes and a hierarchical model for a Poisson time series has been introduced, (Gaver, Jacobs).

The work on the reliability requirements of major caliber ammunition continues; the threshold specified by the model has been implemented operationally (Bailey, Whitaker). Work on the system effectiveness for the NATO Seasparrow continues (Woods).

STATISTICS AND DATA ANALYSIS

New statistical meteorological prediction error models have been developed and assessed (Gaver, Jacobs).

Analysis of bioassay data relevant to toxicological phenomena (Gaver, Jacobs). Research into the assessment of computer software quality has begun (Gaver). Work on the calibration of underwater test ranges continues (Read). A comparative study of two stage estimation of failure rates was accomplished (Sohn).

The department has initiated development of a strong capability in the area of categorical data analysis with a variety of activities (Whitaker, Read, Bailey, Larson, Kemple, Sohn).

A statistical study of monthly attrition of Marine Corps officers has been completed (Read). Study has begun on issues relating to confidence assessments for simulation models used by the Strategic Defense Initiative office Kemple, Bailey, Sovereign, Purdue). Study of stratigraphic correlations in geological data continues (Kemple, Sadler, Droser, Strauss). Study of the Army's Recruiting resource planning system has begun (Larson, Read, Keller).

WARGAMING AND COMBAT ANALYSIS

Work has continued on the stochastic hierarchical modeling of theater combat, (Gaver, Jacobs, Parry).

Work on the battle group logistics support system continues (Schrad, Isakari). The generation of battle enhanced analysis methods continues (Larson, Kemple). The chair of emerging technologies (Marshall) continued its activities in modeling and sponsoring a seminar series. The military worth of staying power is under study (Hughes).

**RELIABILITY REQUIREMENTS FOR COMPONENTS OF MAJOR CALIBER
AMMUNITION**

**M.P. Bailey, Assistant Professor
L.R. Whitaker, Associate Professor
Department of Operations Research
Sponsor and Funding: Naval Weapons Support Center,
Crane Division, Crane, IN**

OBJECTIVE: Multiyear project dealing with the required reliability of components of major caliber ammunition, the goal being a prescribed level of mission effectiveness for naval gunfire support.

SUMMARY: As of 1 Jan 94, every major caliber ammunition component purchased has its reliability threshold established through the use of our model and methodology. All stockpile maintenance actions are also driven using criteria derived from our effort.

The model used to analyze reliability issues is equally suited to determine the effects of improving training of the gun crew. COMNAVSURFLANT is pursuing this initiative. In addition, the same command is proposing that the methodology of linking system performance to mission effectiveness be used to evaluate readiness in all Naval missions.

During the study, it became apparent that there existed times when ships firing NGFS lost calibration in a weapon or a navigational aid. The result was a severe loss in effectiveness of the ship, as well as wasted ammunition and range time. We have developed a methodology, based on statistical process control, which allows the ship to recognize these situations quickly. The method

allows the ship to take expedient corrective action and resume the mission. The methodology is now being tested at the Atlantic Fleet Weapons Test Facility (AFWTF) and will probably be employed operationally before the end of 1996.

PUBLICATION: Bailey, M.P., Callahan, A.J. and Bowden, J., "Managing Ship Performance of Naval Gunfire Support using Statistical Process Control," in Proceedings of the ADPA Conference on Statistical Process Control, (expanded version submitted to Military Operations Research).

CONFERENCE PRESENTATIONS: Bailey, M.P., "Implementation of Reliability Goal Determination Methods in Procurement and Surveillance," JMEMS-Methodology Working Group, Dahlgren VA, September 1993.

Bailey, M.P., Callahan, A.J., and Bowden, J., "Managing Ship Performance of Naval Gunfire Support using Statistical Process Control," ADPA Conference on Statistical Process Control, San Diego, CA, August 1993.

DOD KEY TECHNOLOGY AREA: Computers, Software.

KEYWORDS: Design Automation.

LARGE-SCALE OPTIMIZATION

G.H. Bradley, Professor

G.G. Brown, Professor

R.K. Wood, Associate Professor

Department of Operations Research

Sponsor and Funding: Office of Naval Research

OBJECTIVE: This continuing research program develops theory and algorithms for solution of large-scale optimization models.

SUMMARY: Techniques were developed for automatic exploitation of special structure in branch-and-bound solutions of integer programming problems. The X-System linear/nonlinear/integer optimizer was linked to the GAMS algebraic modeling system to make this state-of-the-art optimizer more widely available to users, especially in the DoD. Game theoretic models and algorithms were developed with applications to the interdiction of illegal drugs and precursor chemicals in Latin America. NETWORK ASSISTANT, a prototypic system of portable C program modules for supporting the construction of efficient network and graph algorithms was successfully implemented. Research began on the persistence of solutions among related mathematical programming models.

PUBLICATIONS: Brown, G. and Vassiliou, A., "Optimizing Disaster Relief: Real-Time Operational and Tactical Decision Support," Naval Research Logistics, Vol. 40, pp. 1-23, 1993.

Wood, K., "Deterministic Network Interdiction," Mathematical and Computer Modeling, Vol. 17, pp. 1-18, 1993.

Wood, K., De Wolfe, D., and Stevens, J., "Setting Military Reenlistment

Bonuses," Naval Research Logistics, Vol. 40, pp. 143-160, 1993.

Brown, G. and Olson, M., "Dynamic Factorization in Large-Scale Optimization," NPS Technical Report NPS-OR-93-008, May 1993, (also to appear in Mathematical Programming).

Brown, G., Coulter, D. and Washburn, A., "Sortie Optimization and Munitions Planning," NPS Technical Report NPS-OR-93-011, May 1993, (also submitted for review).

Brown, G. and Olson, M., "Elastic Modeling with the X-System and GAMS," User's Manual, June 1993.

OTHER: Brown, G., Bausch, D., and Ronen, D., "Dispatching Lube Oil Products," submitted for review.

Wood, K. and Washburn, A., "Game Theoretic Models for Network Interdiction," submitted for review.

CONFERENCE PRESENTATIONS: Bradley, G., "Overview of NETWORK ASSISTANT," ORSA/TIMS Joint National Meeting, San Francisco, CA, 1-4 November 1992.

Bradley, G. and Oliveira, H., "Using NETWORK ASSISTANT to Evaluate Graph and Network Algorithms," ORSA/TIMS Joint National Meeting, San Francisco, CA, 1-4 November 1992.

Wood, K. and Washburn, A., "Game-Theoretic Network Interdiction Models," ORSA/TIMS Joint National Meeting, San Francisco, CA, 1-4 November 1992.

Brown, G., Wood, K., Mamer, J., and McBride, R., "Solving a Large-Scale Generalized Multi-Commodity Flow Problem," ORSA/TIMS Joint National Meeting, San Francisco, CA, 1-4 November 1992.

Bradley, G., "Optimization of Capital Portfolios in the Telephone Industry," Management Science Seminar, University of Chicago, 13 May 1993.

THESES DIRECTED: Osborn, S., "MPAMOD: An Optimization Model for Maritime Patrol Aviation Modernization Planning," Master's Thesis, March 1993, (K. Wood, advisor).

Justice, B., "A Scheduling Model for the U.S. Marine Corps Communications-Electronics School," Master's Thesis, September 1993, (G. Brown and K. Wood, advisors).

Dettbarn, J., "A Model for Scheduling Airborne Early Warning Aircraft for

Counternarcotic Air Interdiction," Master's Thesis, September 1993, (K. Wood, advisor).

Sweeny, J., "An Officer Staffing Goal Model for the U.S. Marine Corps," Master's Thesis, September 1993, (K. Wood, advisor).

Van Brabant, J., "A Monthly Squadron Sortie Scheduling Model for Improved Combat Readiness," Master's Thesis, September 1993, (K. Wood, advisor).

Wu, H., "A Prototypic Model for Scheduling Courses at the Naval Postgraduate School," December 1993, (K. Wood, advisor).

DOD KEY TECHNOLOGY AREA: Other.

KEYWORDS: Optimization, Integer Programming, Network Interdiction.

**EXPLOITING SPECIAL STRUCTURE IN LARGE-SCALE USAF
OPTIMIZATION MODELS**

G.H. Bradley, Professor

G.G. Brown, Professor

R.K. Wood, Associate Professor

Department of Operations Research

Sponsor and Funding: Air Force Office of Scientific Research

OBJECTIVE: This continuing research program develops theory and algorithms for detecting and exploiting special structure in large-scale optimization models used by the USAF for planning conventional air-to-ground munitions procurement.

SUMMARY: Techniques were developed for automatic exploitation of special structure in linear programs and in branch-and-bound solutions of integer programming problems. The X-system linear/non-linear/integer optimizer was successfully married with the GAMS algebraic modeling system to make this state-of-the-art optimizer more widely available to users, especially in the DoD.

PUBLICATIONS: Brown, G., Coulter, D., and Washburn, A., "Sortie Optimization and Munitions Planning," NPS Technical Report NPS-OR-93-011, May 1993, (also submitted for review).

Brown, G. and Olson, M., "Dynamic Factorization in Large-Scale Optimization," NPS Technical Report NPS-OR-93-008, May 1993, (Also to appear in Mathematical Programming).

Brown, G. and Olson, M., "Elastic Modeling with the X-System GAMS," User's Manual, June 1993.

Brown, G. and Vassiliou, A., "Optimizing Disaster Relief: Real-Time Operational And Tactical Decision Support," Naval Research Logistics, Vol. 40, pp. 1-23, 1993.

Wood, K., "Deterministic Network Interdiction," Mathematical and Computer Modeling, Vol. 17, pp. 1-18, 1993.

Wood, K., DeWolfe, D., and Stevens, J., "Setting Military Reenlistment Bonuses," Naval Research Logistics, Vol. 40, pp. 143-160, 1993.

OTHER: Brown, G., Bausch, D., and Ronen, D., "Dispatching Lube Oil Products," submitted for review.

Wood, K. and Washburn, A., "Game Theoretic Models for Network Interdiction," submitted for review.

CONFERENCE PRESENTATIONS: Bradley, G., "Overview of NETWORK ASSISTANT," ORSA/TIMS Joint National Meeting, San Francisco, CA, 1-4 November 1992.

Bradley, G. and Oliveira, H., "Using NETWORK ASSISTANT to Evaluate Algorithms," ORSA/TIMS Joint National Meeting, San Francisco, CA, 1-4 November 1992.

Wood, K. and Washburn, A., "Game-Theoretic Network Interdiction Models," ORSA/TIMS Joint National Meeting, San Francisco, CA, 1-4 November 1992.

Brown, G., Wood, K., Mamer, J., and McBride, R., "Solving a Large-Scale Generalized Multi-Commodity Flow Problem," ORSA/TIMS Joint National Meeting, San Francisco, CA, 1-4 November 1992.

Bradley, G., "Optimization of Capital Portfolios in the Telephone Industry," Management Science Seminar, University of Chicago, IL, 13 May 1993.

THESES DIRECTED: Osborn, A., "MPAMOD: An Optimization Model for Maritime Patrol Aviation Modernization Planning," Master's Thesis, March 1993, (K. Wood, advisor).

Justice, B., "A Scheduling Model for the U.S. Marine Corps Communication-Electronics School," Master's Thesis, September 1993, (G. Brown and K. Wood, advisors).

Dettbarn, J., "A Model for Scheduling Airborne Early Warning Aircraft for Counternarcotic Air Interdiction," Master's Thesis, September 1993, (K. Wood, advisor).

Sweeny, J., "An Officer Staffing Goal Model for the U.S. Marine Corps," Master's Thesis, September 1993, (K. Wood, advisor).

Van Brabant, J., "A Monthly Squadron Sortie Scheduling Model for Improved Combat Readiness," Master's Thesis, September 1993, (K. Wood, advisor).

Wu, H., "A Prototypic Model for Scheduling Courses at the Naval Postgraduate School," Master's Thesis, December 1993, (K. Wood, advisor).

DOD KEY TECHNOLOGY AREA: Other.

KEYWORDS: Large-scale Optimization, Air-to-Ground Munitions.

OPTIMALLY STATIONING UNITS TO BASE (OSUB):
A MODEL FOR BASE CLOSURE

R.F. Dell, Assistant Professor

S.H. Parry, Professor

R.E. Rosenthal, Professor

Department of Operations Research

**Sponsor and Funding: Office Chief of Staff of the Army,
DACS-DM (TABS)**

OBJECTIVE: The goal of this multi-year research project is to provide optimization based decision making tools for the analysis of Army base realignment and closure.

SUMMARY: During the second year (1993) of this multi-year project, the investigators have primarily supported the sponsor's use of an optimization model delivered during the first year of the project. The optimization model (referred to as OSUB) is specifically designed to generate realignment and closure recommendations for maneuver and training installations. OSUB is a bi-criteria mixed integer programming model with the objectives of military value and force stationing cost. OSUB has the ability to analyze the tradeoff between these two objectives and provides a valuable tool where alternative basings of a force structure can be generated and analyzed. Realignments are restricted by a number of constraints which include the need to provide Army units with housing, facilities, maneuver land, deployment, and ranges. Constraints on construction and movement costs are also included to ensure one-time realignment costs are kept within reasonable limits.

OSUB was used in the decision to station a unit returning from overseas at Fort Lewis, Washington. OSUB results were included in the Army's Environment Impact Statement, reviewed for accuracy and reliability, and approved as complete by Lieutenant General Tillelli, Deputy Chief of Staff for Operations and Plans.

THESIS DIRECTED: Gillman, W.G., "Evaluating Army Base's Ability to Support Maneuver Training: A Linear Programming Approach," Master's Thesis, September 1993.

Advising 2 theses in progress.

OTHER: Dell, R.F., Fletcher, C., Parry, S.H., and Rosenthal, R.E., "Modeling Army Maneuver and Training Base Realignment and Closure," submitted to the Military Operations Research Society's RIST prize competition.

DOD KEY TECHNOLOGY AREA: Other.

KEYWORDS: Base Realignment and Closure, Integer Programming Application Facility Location.

**INTERACTIVE SIMULATION AND OPTIMIZATION FOR
SELECTING COAST GUARD LAW ENFORCEMENT ASSETS**

M.P. Bailey, Assistant Professor

R.F. Dell, Associate Professor

Department of Operations Research

**Sponsor and Funding: U.S. Coast Guard Research and
Development Ctr, Systems Analysis Branch**

OBJECTIVE: The goal of this multi-year research project is to aid in the development of LESIM: Law Enforcement SIMulation. LESIM is an on-going United States Coast Guard (USCG) research effort to develop a simulation model capable of assisting with decisions concerning USCG resource allocation, resource scheduling, and tactics.

SUMMARY: The first year of this multi-year project was completed in 1993. The investigators conducted basic research related to the LESIM model and supplied a number of products to the sponsor. Professor Kevin Glazebrook (University of Newcastle Upon Tyne, United Kingdom), at the investigators' request, visited the Naval Postgraduate School and assisted with basic research. The products delivered to the sponsor include: an optimization model to schedule both Coast Guard district assets and Atlantic Area assets operating within the seventh and eighth Coast Guard districts, a review of LESIM's verification and validation plan with proposed improvements, and a document requesting specific LESIM verification testing. A simulation model has been developed to test and

validate the LESIM model. The investigators also participated in two workshops organized by the sponsor which included all the major LESIM participants.

CONFERENCE PRESENTATION: Dell, R.F. and Farmer, R., "Developing Schedules for Coast Guard District Cutters," National Meeting of the Operations Research Society of America and the Institute of Management Science, 16-19 May 1993.

OTHER: Software: Optimization model developed to schedule both Coast Guard district assets and Atlantic Area assets operating within the seventh and eighth Coast Guard districts.

Software: Simulation prototype which shall be used to validate the LESIM model, as well as to examine the behavior of several stochastic models of information flow between law enforcement forces and smuggling agents.

DOD KEY TECHNOLOGY AREA: Software.

KEYWORDS: Simulation, Discrete Optimization, Scheduling, Response Surface Methods.

DAMAGE AGGREGATION MODELS FOR WEAPONS SALVOS

J.D. Esary, Professor

Department of Operations Research

**Sponsor: Naval Air Warfare Center Weapons Division,
China Lake, CA**

Funding: Naval Postgraduate School

OBJECTIVE: Develop reasonable planning models for estimating the aggregate damage caused by multiple hits from weapons salvos.

SUMMARY: This project is a continuation of a project conducted during previous years under the same title. The estimation of the aggregate damage to be achieved as the result of multiple weapons hits is a fundamental aspect of strike planning. At least two measures of effectiveness are pertinent, the expected percentage of the target which is damaged, and the probability that the damage to the target exceeds a threshold sufficient to regard the target as "killed." Models for estimating these measures are of interest generically, and specifically to various subgroups of the Joint Technical Coordinating Committee for Munitions Effectiveness. Results documented during the initial two years concerned empirical rules for estimating the expected percentage of damage of an area target compared to a rule derived from a plausible model, and the first of an emerging family of target configuration and weapons impact scenarios which lead to the plausible model (now called a proportional effects damage aggregation mechanism). Results documented during the third year include extensions to the family of targeting scenarios which lead to a proportional damage aggregation mechanism and the first consideration of dependencies in weapons hit

distributions. Results documented during the fourth year are about the relationship between concepts of subproportional damage aggregation (cumulative and incremental subproportionality) and a fairly general targeting scenario which leads to the stronger incremental type of subproportional damage aggregation. A fundamental vehicle for much of the preceding modeling has been the consideration of cellular targets, i.e. targets that can be viewed as divided into cells of varying importance which are affected separately or in groups by the weapons in the salvo. This year the cellular modeling concept was used in an analysis of the survivability of munitions storage facilities (bomb dumps) by Mr. Yeo Gim Koon, a Project Engineer in the Singapore Ministry of Defence. The computational architecture derived in Mr. Koon's thesis provides a foundation for the development of a cellular target analysis capability using microcomputer spreadsheets.

THESIS DIRECTED: Koon, Yeo Gim, "An Analytical Approach to Assessing the Vulnerability of Bomb Shelters to Aerial Bombing and Artillery Attack," Master's Thesis, September 1993.

DOD KEY TECHNOLOGY AREA: Other.

KEYWORDS: Munitions Effectiveness, Damage Aggregation, Strike Planning, Cellular Targets, Proportional Damage.

METEOROLOGICAL DATA ANALYSIS:
ESTIMATION OF PREDICTION ERROR VARIANCES

D.P. Gaver, Distinguished Professor

P.A. Jacobs, Professor

Department of Operations Research

Sponsor and Funding: Naval Research Laboratory-West

OBJECTIVE: Variance of prediction errors is required in the optimum interpolation analysis used in numerical weather prediction. The purpose of this study is to investigate the relationship of the prediction error variances to other atmospheric parameters in order to improve estimation.

SUMMARY: Statistical models for the prediction error have been formulated which have log-linear scale parameters which include covariates. Data from February 1991 are used to compare the predictive performance of various covariates.

PUBLICATION: Jacobs, P.A. and Gaver, D.P., "A Comparison of Predictors for First-Guess Wind Speed Errors," NPS Technical Report NPS-OR-93-020, December 1993.

DOD KEY TECHNOLOGY AREA:
Environmental Effects.

KEYWORDS: Regression Models for Variances, Optimal Interpolation in Numerical Weather Prediction, Assessment of Predictors, Gaussian Model with Log Linear Scale Parameter.

QUANTITATIVE TOXICOLOGY AND RISK ASSESSMENT

D.P. Gaver, Distinguished Professor

Department of Operations Research

**Sponsor and Funding: Naval Medical Research Institute,
Toxicology Detachment**

OBJECTIVE: To initiate mathematical and statistical work on the interaction between (a) PBPK compartment Models, (b) dose-response models, and (c) risk analysis with emphasis on a military population at risk.

SUMMARY: Models of organic cell response to toxins have been proposed.

PUBLICATION: Carpenter, R.L., Gaver, D.P., and Jacobs, P.A., "An Exploratory Model for Toxic Effects on Cells," NPS Technical Report NPS-OR-93-014, September 1993.

CONFERENCE PRESENTATIONS: Gaver, D.P., Jacobs, P.A., and Carpenter, R.L., "Preliminary Probability Models for Effects of Toxins in Organs,"

ORSA/TIMS Joint National Meeting, Phoenix, AZ, 31 October - 3 November 1993.

Gaver, D.P. and Jacobs, P.A., "An Exploratory Stochastic Model for Toxic Effects on Cells," National Institute of Environmental Health Sciences, Research Triangle Park, NC, 29 September 1993.

DOD KEY TECHNOLOGY AREA:
Environmental Effects.

KEYWORDS: Stochastic Models, Dose-Response Models, Biological Cells, Toxic Chemicals.

MANAGEMENT INDICATOR

D.P. Gaver, Distinguished Professor
P.A. Jacobs, Professor
Department of Operations Research
Sponsor and Funding: NAVAIR (AIR 419)

OBJECTIVE: To develop a reliable aircraft readiness degradation forecasting methodology to assist decision making for maintaining aircraft availability at minimum cost.

SUMMARY: Development of an aircraft readiness degradation forecasting method has been initiated.

OTHER: Chang, T.-J. and Uribe, L., "A Computer Decision Aid Written in PASCAL," July 1993.

THESIS DIRECTED: Chang, T.-J., "Assessing the Possible Return on Investment Resulting from Upgrading a Subsystem," Master's Thesis, March 1993.

DOD KEY TECHNOLOGY AREA: Human-System Interfaces.

KEYWORDS: Return on Investment, Cost of System Re-engineering, Assessment of Uncertainty, Change-point Problems.

ANALYTIC SUPPORT FOR NAVY OPERATIONAL TEST AND EVALUATION

D.P. Gaver, Distinguished Professor
Department of Operations Research
Sponsor and Funding: COMOPTEVFOR

OBJECTIVE: To bring operations research approaches and methodology to bear in Navy OT&E.

SUMMARY: Research has been initiated concerning the assessment of computer software quality and maturity. Initial decision-theoretic models of "how much testing is enough" which incorporate the cost of testing have also been formulated.

THESIS DIRECTED: Burton, D.R., "Software Reliability Management through Metrics," Master's Thesis, March 1993.

OTHER: Gaver, D.P., "Initial Discussion of a Number-of-Tests Decision Rule used by OpTevFor," forthcoming.

DOD KEY TECHNOLOGY AREA: Human-system Interface.

KEYWORDS: Software Reliability, Sample Size Problems, Costs Associated with Testing.

QUANTITATIVE TOXICOLOGY

D.P. Gaver, Distinguished Professor

P.A. Jacobs, Professor

Department of Operations Research

Sponsor and Funding: U.S. Army Biomedical Research and
Development Laboratory

OBJECTIVE: To initiate an effort to provide quantitative, data-based assessments of toxicological phenomena relevant to Army goals and to advance the quantitative methodology needed for the assessments.

SUMMARY: A statistical analysis of data from a histopathologic examination of tissues from Japanese medaka fish has been performed. The study of issues of combining information from different tests of the same environmental object has been initiated.

CONFERENCE PRESENTATIONS: Gaver, D.P. and Jacobs, P.A., "Quantitative Analysis of Bioassay Data from different Biomonitoring Test Systems (BTS)," Army Biomedical Research and Development Project Review, 26-27 October 1993, to appear in proceedings.

Gaver, D.P., invited discussion of G.S. Bayard (EPA), "Combining Epidemiological Studies for Human Health Risk Assessment: Passive Smoking and Dioxin," U.S.E.P.A. and National Institute of Statistical Sciences Workshop on Statistical Methods for Combining Environmental Information, Chapel Hill, NC, 27 September 1993.

OTHER: Gaver, D.P. and Jacobs, P.A., "A Simulation Study of the Behavior of Estimates of the Teratogenic Index," forthcoming.

DOD KEY TECHNOLOGY AREA:
Environmental Effects.

KEYWORDS: Combining Information, Data Analysis of Bioassay Data, Generalized Linear Regression.

**PROBABILISTIC MODELS FOR SHAPES AND HIERARCHICAL BAYESIAN
MODELING AND ESTIMATION**

**D.P. Gaver, Distinguished Professor
P.A. Jacobs, Professor
Department of Operations Research
Sponsor: Office of Naval Research
Funding: Naval Postgraduate School**

OBJECTIVE: To conduct probabilistic and statistical research on a) simple characteristics of random environmental shapes, and b) non-standard data analysis techniques such as non-Gaussian time series prediction and hierarchical statistical models.

SUMMARY: A hierarchical model for a Poisson time series with covariates was introduced and its use in short-term forecasting investigated. Properties of a stochastic greedy bin-packing algorithm were investigated.

PUBLICATIONS: Gaver, D.P., Morrison, J.A. and Silveira, R., "Service-Adaptive Multi-Type Repairman Problems," SIAM Journal of Applied Mathematics, Vol. 53, No. 2, pp. 459-470, April 1993.

Gaver, D.P. and Jacobs, P.A., "Asymptotic Properties of Stochastic Greedy Bin-Packing," NPS Technical Report NPS-OR-93-017, November 1993.

Gaver, D.P., "Modeling and Simulation in the Military: Statistical Issues and Opportunities," in Proceedings of the Thirty-Eight Conference on the Design of Experiments in Army Research Development and Testing, Army Research Report 93-2, 1993.

CONFERENCE PRESENTATIONS: Gaver, D.P., Coffman, Jr., E.G., Jacobs,

P.A., and Wright, P.E., "Adaptive Packing," Applied Probability in Engineering, Computer and Communication Sciences, Paris, France, 16-18 June 1993.

Gaver, D.P., "Modeling and Simulation in the Military: Statistical Issues and Opportunities," invited keynote address, Thirty-Eighth Army Conference on Design of Experiments, 1993.

OTHER: Gaver, D.P., "Quantitative Modeling and Analysis in Environmental Studies," Chapter of a book scheduled to be published.

Almeida, R., Gaver, D.P., and Jacobs, P.A., "Simple Probability Models for Assessing the Value of Information in Defense Against Missile Attack," submitted for publication.

THESIS DIRECTED: Howard, T.L., "An Analytical Model for the Treatment and Evacuation of Casualties in a Low-Intensity Conflict," Master's Thesis, March 1993.

DOD KEY TECHNOLOGY AREA: Human-system Interfaces.

KEYWORDS: Prediction for a Hierarchical Poisson Time Series Model, Bin Packing, The Value of Information.

STOCHASTIC HIERARCHICAL MODELING OF THEATER COMBAT

D.P. Gaver, Distinguished Professor

S.H. Parry, Professor

P.A. Jacobs, Professor

Department of Operations Research

**Sponsor and Funding: Conventional Forces Analysis Division,
J-8, The Joint Staff**

OBJECTIVE: To continue development of an architecture for probabilistic models of joint theater level combat.

SUMMARY: Research has been continued towards the development of an architecture of a stochastic model of joint theater level combat. Work has concentrated on models for updating the perception of the theater using sensor information and models for the air campaign.

CONFERENCE PRESENTATION: Youngren, M., Gaver, D.P., Jacobs, P.A., and Parry, S.H., "Future Stochastic Theater Level Combat Modeling," Working Group 14, Military Operations Research Society, Dayton, OH, June 1993.

Youngren, M., Gaver, D.P., and Jacobs, P.A., "Perception Updating in the Future Theater Level Combat Model," Sensor Modelling Workshop,

AMSAA, Aberdeen Proving Ground, MD,
25-26 May 1993.

Gaver, D.P., Jacobs, P.A., and Parry, S.H., "Modelling Sensor Effects," Interim Progress Review, The Joint Staff, 28 October 1993.

THESIS DIRECTED: Schmidt, K., "A Framework for Incorporating Battlefield Purpose and Intelligence," Master's Thesis, September 1993.

OTHER: Yamauchi, H., "Stochwars," C++ software, October 1993.

DOD KEY TECHNOLOGY AREA: Human-System Interface.

KEYWORDS: Combat Models, Bayesian Perception Updating, Decision Analysis.

MODEL FOR TERRITORY REALIGNMENT

T. Halwach, Adjunct Professor

S. Lawphongpanich, Associate Professor

Department of Operations Research

Sponsor: Naval Recruiting Command

Funding: Naval Personnel Research and Development Center

OBJECTIVE: To develop an optimization based tool for realigning the Naval Recruiting Structure.

SUMMARY: This research is an extension of a previous research titled "Optimal Recruiting Structure." In this research we propose to extend the optimization models developed earlier to include the following:

(a) Estimated driving time between two points. In the previous study, the driving time is not used. Instead, the great circle distance between two points was used in

determining the optimal location for recruiting stations.

(b) Development of a station location model to include a lease, communication and transportation costs.

(c) Development of a multidistrict station allocation model to determine support budget requirements for the new 31 district structure.

DOD KEY TECHNOLOGY AREA: Other.

KEYWORDS: Optimization, Resource Allocation, Recruiting, Shortest Path.

OPTIMAL REALIGNMENT OF THE U.S. ARMY RECRUITING STATIONS

S. Lawphongpanich, Associate Professor

S.Y. Sohn, Assistant Professor

Department of Operations Research

Sponsor and Funding: U.S. Army Recruiting Command

OBJECTIVE: To develop an optimization based tool for realigning the Army recruiting stations.

SUMMARY: The decision to close, consolidate and relocate recruiting stations has a profound impact on the Army's recruiting efforts. In particular, the number and locations of stations that are 'optimally' determined can provide Army recruiters with competitive advantages over recruiters from the other services. During this period, we develop a statistical model to forecast the number of contracts that can be obtained from a given zip code. Using this statistical model, we developed three optimization

models. First model partitions the continental United States into a number of recruiting battalions. Second model decides which existing recruiting stations to remain open and then assigns recruiters to these stations. Third model decides which existing recruiting companies to remain open and then assigns stations to these companies.

PUBLICATIONS: We are in the process of writing the final report for this study.

DOD KEY TECHNOLOGY AREA: Other.

KEYWORDS: Optimization, Recruiting, Resource Allocation.

**FORECASTING THE CONDITIONAL DEP LOSS PROBABILITIES FOR
OPTIMAL MISSIONING**

P.R. Milch, Professor

S. Lawphongpanich, Associate Professor

L. Whitaker, Associate Professor

Department of Operations Research

Sponsor and Funding: U.S. Army Recruiting Command

OBJECTIVE: To develop a methodology to forecast the probability that a recruit fails to join the Army after having signed an enlistment contract. The probability is dependent upon the time a recruit must remain in the Delayed Entry Program (DEP) as well as other factors.

SUMMARY: There have been many studies on DEP loss. Most of these provide analysis and recommendation but few lead to actual tools usable by USAREC. We propose to provide USAREC with a decision aid to assist USAREC in setting the proper recruiting missions for its recruiting brigades. We formulated the problem of setting the proper recruiting mission as an optimization

and used GAMS (A General Algebraic Modeling System) to obtain an optimal answer. Important inputs for the optimization model are the DEP loss probabilities, both conditional and unconditional. We are in the process of constructing a statistical model to estimate them.

THESIS DIRECTED: Burris, B.D., CAPT, "Missioning with Minimal Delayed Entry Program Loss," Master's Thesis, September 1993.

DOD KEY TECHNOLOGY AREA: Other.

KEYWORDS: Optimization, Forecasting, Conditional Probability, Recruiting, Delayed Entry Program.

THE MILITARY WORTH OF STAYING POWER

W.P. Hughes, Jr., Senior Lecturer

Department of Operations Research

Sponsor and Funding: Naval Surface Warfare Center, Carderock

OBJECTIVE: To evaluate the military worth of a contemporary warship's ability to continue fighting after taking one or more hits, which is its "staying power." Emphasis is on missile hits.

SUMMARY: The research was completed in unclassified form and delivered to the sponsor in September 1993. After a review, the sponsor decided that the study would be even more useful if a version using classified information were developed. A classified study is in preparation. The principal conclusions of the study are:

(1) In missile combat the two most important advantages a force can have are:

a. first detection and targeting such that all enemy units posing a threat are put out of action before they can reply.

b. survivability through defense in depth.

(2) These two advantages cannot be depended on in joint littoral warfare operations. In an exchange of missile salvos, highly capable surface warships with weak staying power are liable to suffer severe losses to an inferior enemy who conducts a bold attack.

(3) Contemporary designs of multipurpose surface combatants such as the CG-47 and DDG-51 are out of balance, in the sense that they have strong offensive and defensive firepower but weak staying power. The result is an unstable situation in littoral operations.

(4) Combat stability will be restored by a balanced design: one with greater staying power. The benefits from enhancing staying power are to sustain all attributes of a warship, preserve its deliverable fighting power, and help to assure that a superior force will consistently prevail over a nominally inferior one.

PUBLICATION: Hughes, W.P., Jr., "A Salvo Model of Warships in Missile Combat Used to Evaluate their Staying Power," Naval Research Logistics, accepted for publication for Fall 1994.

CONFERENCE PRESENTATION: Hughes, W.P., Jr., "Naval Forces in Joint Littoral Warfare," 61st MORS Symposium Working, 22 June 1993.

DOD KEY TECHNOLOGY AREA: Other.

KEYWORDS: Naval Combat, Survivability, Vulnerability, Warship.

STANAG SIMULATION AND ANALYSIS

W.G. Kemple, Assistant Professor

M.P. Bailey, Assistant Professor

M.G. Sovereign, Professor

Department of Operations Research

Sponsor and Funding: Joint Interoperability Engineering

Organization (JIEO), Fort Monmouth, NJ

OBJECTIVE: The objectives of this project were twofold: first, to discover any weaknesses in NATO's international network numbering and routing scheme promulgated in NATO Standardization Agreement (STANAG) 4214; and second, to explore changes to the STANAG proposed to improve performance.

SUMMARY: An object-oriented simulation model was developed to evaluate the effectiveness of STANAG 4214. The model simulates communication systems using the STANAG 4214 protocol to isolate discrepancies which could lead to the inability to successfully complete calls within the system or cause system overload. Ambiguities in the STANAG were uncovered, one of which would cause calls to fail, and another that could result in fewer trunks utilized than feasible or calls looping through the system, creating unnecessary overload. The model simulates protocol modifications created to correct these discrepancies and verifies their effectiveness in making the protocol more robust. Results show that these modifications improve STANAG call completion rate from a potential low of under 70 percent to 100 percent, while simultaneously

easing STANAG restrictions on lateral communication connections. The model (software and a user's manual) was delivered to JIEO in 1993, and we are still working with them to use it to answer some new questions. The model is menu-driven with both graphical and hard copy output, making it useful to network planners, protocol designers, and tactical communications officers.

THESIS DIRECTED: Dorko, M. and Schultz, R., "A Simulation and Evaluation of NATO Standardization Agreement (STANAG) 4214," Master's Thesis, September 1993.

OTHER: This research was briefed to the J6, MGEN Kelley; to N81, RADM Oliver; and to the USEUROCOM STANAG 4214 working group. It was also presented at the Winter Simulation Conference in December 1993 and published in a refereed proceedings article. Both a model (software) and a user's manual were developed.

DOD KEY TECHNOLOGY AREA: Communications Networking.

KEYWORDS: Communications Protocol, NATO Communications, Communications Network Simulation.

VARIABLE RESOLUTION COMBAT SIMULATION

W.G. Kemple, Assistant Professor

M.P. Bailey, Assistant Professor

M.G. Sovereign, Professor

P. Purdue, Chairman and Professor

Department of Operations Research

**Sponsor and Funding: Strategic Defense Initiative Office (SDIO),
Washington, DC**

OBJECTIVE: The objectives of this two year project were threefold: to participate in the development and refinement of procedures to be used in performing confidence assessments on simulation models nominated for inclusion in the SDIO Analytical Tool Box (ATB); to participate in confidence assessment teams formed to evaluate models nominated for inclusion in the ATB; and to develop a taxonomy of model dimensionality and resolution to be used in confidence assessments.

SUMMARY: Funding was not received until March 1993, and our efforts began when we attended the 13-14 April 1993 ATB meeting at SAIC, San Diego. Meetings were held between the PI and the ATB Project Officer to solidify our role; we were to focus on procedure development and confidence assessments the first year, and confidence assessments and the taxonomy the second. We joined and participated in the confidence assessment and VV&A working groups, and the PI was appointed to the ATB Standards Committee. We attended the other two ATB meetings held in FY93, and hosted the second in September. We also participated in the three assessments performed since we joined the ATB: SSGM, La Jolla, CA, June 1993; EADSIM, Huntsville, AL, July 1993; and WILMA, Washington, DC,

September 1993.

OTHER: We participated in drafting and editing:

"Face Validity Assessment Plan," NTF Technical Information Center Number 5654, 30 May 1993.

"ATB CANG White Paper on Confidence Assessment Process," ATB CANG Library document, ATB-CA-06-06A-930614-4, Revision E, 14 June 1993.

"Analytical Tool Box Level 2 ATB Certification Assessment Plan," NTF Technical Information Center Number ATB-CA-05-1B-930000-0, Working Draft version D.1, 15 September 1993.

"SSGM Face Validity Assessment Report," 1993.

"EADSIM Face Validity Assessment Report," 1993.

"WILMA Face Validity Assessment Report," 1993.

We also have one student working on a thesis that originated from this project.

DOD KEY TECHNOLOGY AREA: Software.

KEYWORDS: Simulation, Confidence Assessment, Theater Missile Defense.

STRATIGRAPHIC CORRELATION AS CONSTRAINED OPTIMIZATION:
EXTENDING GRAPHICAL CORRELATION TO N DIMENSIONS

W.G. Kemple, Assistant Professor
Department of Operations Research
Collaborative research with:

Peter M. Sadler, Professor
Mary L. Droser, Assistant Professor
David Straus, Professor
University of California, Riverside

Sponsor and Funding: National Science Foundation, Washington, DC

OBJECTIVE: An ongoing research program to solve the stratigraphic correlation problem (fusing geological data to develop a time scale for rocks based on fossils they contain) by combining expert knowledge with techniques from operations research.

SUMMARY: Three colleagues at the University of California, Riverside and I were awarded parallel two-year grants by the NSF for collaborative research to continue development of our methodology and apply it to fossil data from the mid-Ordovician period, from the Great Basin of California, Nevada, and Utah. The paleontologists on the team have conducted preliminary inspections of four of the sections and begun collecting fossils from key sections. During one trip to NPS by Sadler, and one by Kemple to UCR, we have completed preliminary coding of a new, greatly enhanced version of our FORTRAN program. Among other things, the new version exploits results obtained by Dell, Kemple, and Tovey at NPS to significantly reduce solution times, and graphics developed by Sadler to aid in tuning the solution algorithm. We gave an invited presentation to the Annual Seminar of the Paleontology Group, AMOCO Research, in December 1992, one of only three presentations invited from outside of the company. These three were chosen to present the state of the art in stratigraphic

correlation. This in turn led to an invitation to write a chapter for a volume in the special publications series of the Society of Economic Paleontologists and Mineralogists on Graphical Correlation, which has been submitted.

CONFERENCE PRESENTATIONS: Kemple, W., Dell, R., and Tovey, C., "Applying Tabu Search and Simulated Annealing to the Stratigraphic Correlation Problem," National Meeting of the Operations Research Society of America and the Institute of Management Science, November 1992.

Sadler, P., Kemple, W., and Straus, D., "Simultaneous Graphical Correlation of Multiple Sections," Annual Paleontology Seminar of the Paleontology Group, AMOCO Research, December 1992.

Kemple, W., Dell, R., and Tovey, C., "Tabu Search and Simulated Annealing Applied to the Stratigraphic Correlation Problem," seminar in Operations Research, Naval Postgraduate School, February 1993.

Kemple, W., Dell, R., and Tovey, C., "Heuristic Selection through Experimentation: Tabu Search and Simulated Annealing Applied to the Stratigraphic Correlation Problem," University of California, Riverside, Statistics Department Colloquium, April 1993.

OTHER: During the Winter Quarter, while on sabbatical leave, Sadler taught our method for two weeks for a graduate seminar in paleontology and used the software we developed. One book chapter has been submitted and two papers are in progress. Several enhancements have been incorporated into a new version of our computer program to make it run much faster and provide graphical displays of the solution process (useful in adjusting the solution parameters). Further enhancements will incorporate penalty weights that we have developed based

on the average gap between fossil finds and allow geologists to examine hypotheses about unusual disturbances of the data.

DOD KEY TECHNOLOGY AREA: Software.

KEYWORDS: Graphical Correlation, Stratigraphic Correlation, Combinatorial Optimization, Simulated Annealing.

BATTLE ENHANCED ANALYSIS METHODOLOGIES

H. Larson, Professor

W. Kemple, Assistant Professor

Department of Operations Research

**Sponsor and Funding: U.S. Army Training and Analysis Command,
Monterey, CA**

OBJECTIVE: Continues development of graphic displays of performance of battalion-sized units in realistic training environments, with emphasis on indirect fire assessments. Document and improve the ease of display creation.

SUMMARY: The first year of the Battle Enhanced Analysis Methodologies project illustrated the use of computer graphics in describing the performance of battalion-sized units in simulated defensive combat. In addition, simple uncluttered displays that portray the movements and interactions of company (or higher) sized units throughout a battle were described. These descriptions are data-based and objective, providing useful critiques of actual performance according to standard Army doctrine.

In this second year, the actual production of the derived displays was simplified, using a single platform rather than the initial requirement of several. The major new displays derived portray the destructive potential of indirect fire weapons in the defense, using the same units as the direct fire displays. This allows separate and joint examination of the direct and indirect fire destructive potential, providing, among other things, objective measures of the synchronization and agility of a force, as well as indicators of its

intelligence function.

PUBLICATIONS: Larson, H.J. and Kemple, W.G., "Graphical Displays of Synchronization of Tactical Units," NPS Technical Report NPS-OR-93-010, March 1993.

Kemple, W., Dryer, D., Fernan, J., Lamont, R., Larson, H., and Nelson, M., "Graphical Indicators of Battlefield Performance," in Proceedings of the 25th Symposium on the Interface, University of California, Berkeley, 1993.

Larson, H.J., Kemple, W., and Dryer, D.A., "Visualizing Synchronization of Tactical Units," accepted for publication in Mathematical and Computer Modeling, Combat Modeling issue.

CONFERENCE PRESENTATIONS: Kemple, W., Dryer, D., Fernan, J., Lamont, R., Larson, H., and Nelson, M., "Graphical Indicators of Battlefield Performance," 25th Symposium on the Interface, San Diego, CA, March 1993.

Fernan, J., "Nonlinear Battle Analysis Visual Display Indicators," Working Group 33, 61st Military Operations Research Symposium, Wright-Patterson AFB, OH, June 1993.

DOD KEY TECHNOLOGY AREA: Software.

KEYWORDS: Synchronization, Agility, Computer Graphics.

ANALYSIS OF RECRUITING RESOURCE PLANNING SYSTEMS

H. Larson, Professor

R. Read, Professor

Department of Operations Research

C. Keller, DRMEC

Sponsor and Funding: U.S. Army Recruiting Command

OBJECTIVE: The original goal was to reconcile/explain outputs produced by two different resource planning systems used by the Army Recruiting Command. Later amended to estimate elasticities of enlistment bonuses and education benefits employed in one of these models.

SUMMARY: Initial time was spent in familiarization with the Forecasting and Allocation of Army Recruiting Resources Study (FAARRS) and the Sequential Hierarchical Allocation of Resource Elements (SHARE) models, as well as the Job Performance Measures/Cost Performance Tradeoff (JPM/CPT) model. The FAARRS/SHARE model outputs of optimal resource allocations were initially found to differ substantially from those of

the JPM/CPT model, based on the same inputs. Subsequent to start of work on this effort, a new study re-estimated the elasticities used in the JPM/CPT model, which brought the outputs more in line with each other. It is thought that the elasticities for enlistment bonuses and education benefits, from this new study, are still not very accurate; the current focus of this project is the accurate estimation of these two elasticities. Some review of previous modeling effort has been accomplished and tentative arrangements for acquisition of some necessary data have been made.

DOD KEY TECHNOLOGY AREA: Other.

KEYWORDS: Elasticities, Bonuses.

CNO CHAIR OF EMERGING TECHNOLOGIES

K.T. Marshall, Professor

Department of Operations Research

Sponsor and Funding: Office of the Chief of Naval Operations
(OP-091)

OBJECTIVE: This Chair was established in 1990 to provide a direct relationship between the Director, Office of Navy Requirements for Research and Development, Test and Evaluation (OP-091) and the Superintendent of the Naval Postgraduate School (NPS) in order to establish a focused research program that examines the military implications of emerging technologies, and foster interactions between NPS and the Navy R&D community.

SUMMARY: Approximately one quarter year was devoted to the Chair in FY93. Principal activities included: (1) a seminar involving NPS students and faculty in countering theater ballistic missiles (TBM's), (2) modeling RDT&E resource allocations, (3) completed a report demonstrating NPS uniqueness in teaching military technologies, and (4) pursued interests in modeling search for short range ballistic missile launchers, target identification problems, using ASW concepts to finding land-based targets.

PUBLICATIONS: Marshall, K.T., Conner, G.W., and Ehlers, M.A., "Countering Short Range Ballistic Missiles," NPS Technical Report NPS-OR-93-009, January 1993, (submitted for publication in Military Operations Research).

Marshall, K.T., "The Naval Postgraduate School and Unrestricted Line Officer Graduate Education," Naval Postgraduate School Report, October 1993.

CONFERENCE PRESENTATIONS: Marshall, K.T., "Influence Diagrams and the Value of Information in Decision Modeling," invited tutorial, 61st Military Operations Research Society Symposium (MORS), AFIT, 22-24 June 1993.

Marshall, K.T., "The Analytic Hierarchy Process (AHP): How it Works, and Associated Problems," Department of Operations Research Seminar, 17 November 1993.

THESES DIRECTED: Hair, Thomas L., LT, USN, "The Application of Search Theory to the Timely Location of Tactical Ballistic Missiles," Master's Thesis, March 1993.

Reifenberger, Robert A., LT, USN, "Decision Analysis Applied to the Deployment of Modularized Ocean Basing System," Master's Thesis, September 1993.

Mattis, Joseph P., "LCDR, USN, "The Application of Random Search Theory to the Detection of Tactical Ballistic Missile Launchers," Master's Thesis, September 1993.

McQuail, William H., "Evaluating the Analytic Hierarchy Process and Recommended Modifications for its Use in Mult-Attribute Decision Making," Master's Thesis, September 1993.

Simpson, David, LCDR, USN, "DSP Satellite Cueing for Tactical Ballistic Missile Defense (U), Master's Thesis, September 1993.

DOD KEY TECHNOLOGY AREA: Sensors.

**KEYWORDS: Decision Analysis, Search
and Detection.**

DELAYED ENTRY PROGRAM MANAGEMENT OVERVIEW MODEL (DEPMOM)

P.R. Milch, Professor

Department of Operations Research

Sponsor and Funding: U.S. Army Recruiting Command (USAREC)

OBJECTIVE: Provide USAREC management of the Delayed Entry Program (DEP) with a computer based user-friendly tool to monitor losses among various categories of potential recruits in the DEP.

SUMMARY: Two PC-based computer models were constructed in the language APL. The first model called CONVERT has the task to convert the USAREC provided ASCII files to appropriate APL data files which are somewhat presorted to accommodate their use by the second model called DEPMOM. DEPMOM computes lossrates for various categories of potential recruits in the DEP. These categories may be specified by the

user in terms of their date (year and month) of contract, "mission box number" and contracted length of stay in the DEP. The term "mission box number" specifies one of twenty-two different categories dependent on educational level, mental score, gender and prior service record.

PUBLICATIONS: A final report including user manuals for both models to be submitted to the sponsor is in progress.

DOD KEY TECHNOLOGY AREA: Other.

KEYWORDS: File Management, Data Analysis.

ATTRITION RATE GENERATION FOR MANPOWER MODELS

R.R. Read, Professor

Department of Operations Research

Sponsor and Funding: HQ USMC, Code MI

OBJECTIVE: This is a continuing project. The goal is to build a general purpose system that will convert officer personnel data into attrition probabilities that are valid for time intervals of several lengths, and sensitive to other important classifying parameters. Rank, years commissioned service, occupation specialty are major discriminators but others, such as commissioning source, gender, etc can be required as well. These requirements have the effect of inducing a large number of cells which have low personnel inventory and the building of a rate generator under these circumstances poses the major problem. Modern multi-parameter estimation schemes have been tested.

SUMMARY: Previous work has supplied a validated method for the one year lead time window. This method has been implemented into the Marine Corps manpower models by a commercial organization. This year's work dealt the refinement of attrition rates for shorter time periods, specifically one month and multiples of one month. Monthly attritions are necessarily much smaller than yearly attritions, and the statistical modelling is much more difficult. Some descriptive models have been developed using logistic regression techniques. The standard asymptotic test procedures are inappropriate for defending the chosen models in the absolute sense, but methods for the relative

comparison of competing models are believed to be suitable. It should be possible to adjust the monthly rates so that they are compatible with annual rates in an appropriate sense and thereby have a usable system.

The data are separated by grade and the nine MOS categories in the ORG system. The most important effects uncovered are zone and months. Three promotion zones: in & below, once passed over, and twice passed over have very pronounced effects upon the behavior of attrition rates. The twelve months themselves are also important, but they can be aggregated into four categories: those with low, moderate, high, and very high attrition. Occasionally some selected two factor interactions stand out. The years, 1982-1992, are also quite important, but of course they have no predictive value. Instead, it was found that the unemployment rate (lagged by three months) emerged as a useful covariate. Unimportant effects include gender and the dates of convening of the promotion boards.

PUBLICATION: Read, R.R., "Descriptive Model of Monthly Officer Attrition," NPS Technical Report NPS-OR-93-004, November 1992.

DOD KEY TECHNOLOGY AREA: Design Automation.

KEYWORDS: Manpower Models, Attrition Rates, Multiparameter Estimation.

RANGE CALIBRATION STUDIES

R.R. Read, Professor

Department of Operations Research

Sponsor and Funding: NUWES, Keyport, WA

OBJECTIVE: This is a continuing project. NUWES operates several underwater vehicle tracking ranges of the short baseline type. That is, path segments are developed from a network of bottom based three dimensional tracking arrays, and it is necessary to splice together the path segments contributed by individual arrays in order to study the overall behavior of the vehicle. Unfortunately there exist serious mismatches, often times fifty feet or more, in the attempt to make ends meet. This problem has been present since the opening of the ranges over thirty years ago, and all previous error budgets and interpretations have failed to account for errors of this magnitude. In previous work we have identified important error sources in the ray tracing algorithm which account for about one third of the total separation error. A number of our suggestions have been made operational by the sponsor and the calibration of the range has improved.

SUMMARY: In the present period we have sought to categorize the mismatches into a handful of types. Much information can be gleaned from the "triple overlap" regions, i.e. those regions in the range whose acoustic signals can be heard by three arrays (roughly positioned to form an equilateral triangle). For data in these regions we can use long baseline methods to convert acoustic signals into vehicular track. Any array that shares a triple overlap region with each of six other arrays (in six directions separated by about 60 degrees each) is called an "interior" array. For each of the

six triple overlap regions, the pairs of noninterior arrays can be used to generate consensus positions which can be compared with the position produced by the interior array; presumably the consensus of two would have the greater stability. The information obtainable could lead to prioritizing choices of corrective action.

More explicitly, there are four major conditions. First, if all six positions produced by the interior array were below (above) the consensus positions then the presumed depth of the interior array may be greater (lesser) than the actual. This effect may be confounded with the errors in the elevation angle used to initialize the ray tracing algorithm. Second, if the consensus and test positions are all at the same depth, then it should be an easy matter to identify and correct a horizontal offset in the location of the interior array. Third, the plane of the test positions can be compared with that of the consensus positions. Should one be canted relative to the other, then the array tilts may be in error. Fourth, the test positions may be systematically rotated in a common direction relative to the consensus positions. Such a condition supports an error in the array azimuth angle (ZROT).

Naturally all four forms of error are likely to be encountered simultaneously in an operational situation. Because of this, there is need to develop a strategy for deciding upon the most likely combination of effects as well as a step size for modifying the interior

array parameters for use in the next step of the iteration. The present effort is at this point. Details are in the technical report. The idiosyncrasies of real data include the facts that seldom do we get a vehicle traversing through all six triple overlap regions on the same day, and occasionally the depth-velocity sound speed information is not current.

PUBLICATION: Cooper, C. and Read,

R.R., "Range Calibration Studies Interim Report," NPS Technical Report NPS-OR-93-012, May 1993.

DOD KEY TECHNOLOGY AREA: Design Automation.

KEYWORDS: Calibration, Underwater Sensing.

BATTLE GROUP LOGISTICS SUPPORT SYSTEM

D.A. Schrady, Professor
Department of Operations Research
S. Isakari, Professional Staff Member
Department of Computer Sciences
Sponsor and Funding: CNO N4 and N6

OBJECTIVE: The goal of this project was to restructure and extend the prototype version of the Battle Group Logistics Coordinator Support Systems, BGLCSS, for the Navy Joint Maritime Command Information Systems, JMCIS, and to do so with the "2.1 Unified Build" software release in late FY94.

SUMMARY: The stand-alone PC BGLCSS prototype software had been demonstrated in a number of fleet exercises and determined to be a fleet requirement. Restructuring to the C language and a UNIX workstation was required. Further changes were that certain inputs made manually in the PC version would be acquired from the track database in JMCIS. Finally a number of features of the PC version would be modified based on operational experience. Overall design and graphical user interface creation was accomplished in FY92. In FY93 programming of nearly all functionally has been completed and five demonstrations were given. Strike ordnance use planning factors were developed and needed ship, aircraft, fuels and ordnance databases developed. Program refinements, on-line help, and integration into JMCIS are tasks remaining to be accomplished.

PUBLICATION: Schrady, D.A., "Carrier

Strike Ordnance Planning Factors: Desert Storm Experience (U)," NPS Technical Report NPS-OR-93-021, December 1993.

CONFERENCE PRESENTATIONS: Five presentations and demonstrations were given:

(1) SPAWAR for SPAWAR, N4, and N6 personnel, 28 July 1993.

(2) Secure Tactical Data Network-4 Exercise, NRaD, San Diego, CA, 1-14 September 1993.

(3) JMCIS Requirements Working Group, Dam Neck, VA, 18-20 October 1993.

(4) Naval Tactical Command System Support Meeting, North Island, San Diego, CA, 7-8 December 1993.

(5) Logistics Wargame 94, Naval War College, Newport, RI, 10-14 January 1993.

THESIS DIRECTED: Schiffman, D.L., "An Underway Replenishment Module for the Battle Group Logistics Coordinator Support System," Master's Thesis, September 1993.

DOD KEY TECHNOLOGY AREA: Other.

KEYWORDS: Naval Logistics, Combatant Logistics, Tactical Logistics.

**A MONTE-CARLO STUDY FOR A TWO-STAGE
ESTIMATION OF RANDOM FAILURE RATE OF WEAPON SYSTEMS**

S.Y. Sohn, Assistant Professor

Department of Operations Research

Sponsor and Funding: Naval Postgraduate School

OBJECTIVE: The goal of this project was to compare estimation methods for analyzing random event rate of the Poisson process.

SUMMARY: In this paper, a random effect Poisson regression model was considered for the prediction of the failure rate which would follow a lognormal distribution. A two-stage procedure was used to obtain the regression estimator of the failure rate as well as the shrinkage estimator. These estimators were compared to both the raw estimator which entirely depends on the historical failure records and a shrinkage estimator in which a gamma distribution is used mistakenly in place of the lognormal prior distribution. Results of Monte-Carlo simulation indicated the following in terms of the MSE: (1) overall, the shrinkage estimator based on the lognormal prior distribution performs best; (2) with the moderate variability in the failure rates (0-

2.5), the performance of the shrinkage estimator based on the gamma distribution is not significantly different from that of the shrinkage estimator based on the lognormal distribution; and (3) when there exists considerable variability in the failure rates (0-10), the raw estimator appears to replace shrinkage estimators. In terms of the Bias, the raw estimator performs better than the others.

OTHER: Sohn, S.Y., "A Comparative Study of Four Estimators for Analyzing the Random Event Rate of Poisson Process," Journal of Statistical Computation and Simulation, Vol. 49, pp. 1-10, 1994.

DOD KEY TECHNOLOGY AREA: Other.

KEYWORDS: Poisson Regression, Lognormal Distribution, Shrinkage Estimator, Two-Stage Estimation, Maximum Likelihood Estimation.

OPTIMAL LEVEL OF THE U.S. ARMY ADVERTISING BUDGET

**S.Y. Sohn, Assistant Professor
Department of Operations Research
N. Webb, Assistant Professor, DDMI
Sponsor and Funding: U.S. Army Recruiting Command**

OBJECTIVE: The goal of this project was to analyze the problem of allocation of advertising resources faced by the USAREC. The following is the summary of the on-going project.

SUMMARY: The problem was defined in two stages. In the first stage, young men and women are made aware of opportunities to enlist in the military through media and other advertising efforts. In the second stage, awareness is translated into signed contracts or enlistments. The number of enlistments is a function of awareness (advertising expenditures), recruiting efforts,

incentive and bonus programs and other labor market conditions. We concluded the discovery phase of the project, and have made significant progress in developing a functional form for the models we intended to employ. The analysis of the extent advertising literature was nearly complete. We currently plan to run preliminary versions of the following models: the translog cost function and the rational expectations model suggested by Dr. Wegner at USAREC.

DOD KEY TECHNOLOGY AREA: Other.

KEYWORDS: Advertising Elasticity, Translog Cost Function.

FREQUENCY PLANNING

A. Washburn, Professor

Department of Operations Research

Sponsor and Funding: Department of Defense

OBJECTIVE: This research concerns a network of direction finding stations that attempts to locate a target by triangulation. The frequency emitted by the target is not predictable, and each station can only monitor a fixed number of frequencies. The problem is to calculate the target location probability p for a given "tasking" of frequencies to stations, and also to determine the optimal tasking if possible. Past work has concentrated on calculating an approximate p efficiently by an analytic technique, and on finding a locally optimal tasking by first order methods. The current work is a continuation.

SUMMARY: Some modern techniques (simulated annealing, genetic algorithm) for combinatorial optimization were explored, but none seem to be an improvement on the old first order method. Work on improv-

ing the evaluation of the objective function was more fruitful. In particular, Monte Carlo simulation seems to compete very well with the old analytic method in the sense of providing more accuracy per unit computational effort. New first order techniques for optimization were developed that deal with the sampling error that is inherent in Monte Carlo techniques. All things considered, the Monte Carlo method of determining an optimal tasking appears to be superior to the analytic method.

OTHER: This work was done in cooperation with Lyn Thomas, a summer visitor from U. Edinburgh.

DOD KEY TECHNOLOGY AREA: Other.

KEYWORDS: Combinatorial, Optimization, Direction Finding.

CATEGORICAL DATA ANALYSIS

L.R. Whitaker, Associate Professor

R.R. Read, Professor

M. Bailey, Associate Professor

W. Kemple, Assistant Professor

S.Y. Sohn, Assistant Professor

Department of Operations Research

Sponsor and Funding: Naval Postgraduate School

OBJECTIVE: The purpose of this two year project is to fund OR faculty to gain expertise in the area of categorical data analysis. It is vital that this expertise be of a practical nature as well as theoretical. Thus the analysis of data of interest to DoD sponsors directed our first year work. Ultimately, our goals are to identify sponsors for reimbursable research, give our students the tools that they need to analyze this type, and to contribute to the literature in this area.

SUMMARY: Even though funding for this research was limited to 2.5 faculty quarters, we have accomplished more than our original first year goals. We now have the ability to analyze large and fairly complex categorical data sets. Specifically, Professors Whitaker and Read have continued to refine their analysis of the Operational Propulsion Plan Exam data which has been used as a case study for OA3105. At the request of the Marine Corp Manpower and Analysis Branch, Professors Read and Whitaker have also looked into the problem of success at Officer Candidate School, ASVAB waiver and race. Professor Read has completed an analysis of officer attrition rates for the Marine Corp. Professor Sohn has completed an analysis of transmission line length and outage rates. Professors Whitaker, Larson and LCDR Hosford have taken the first hard

look at the MK46 acquisition rate data. Preliminary analysis reveals a structure rich enough that it deserves further study. Professor Whitaker and several students have been looking at losses of Army recruits while in the Delayed Entry Program for USAREC. Professor Larson and a student have considered a similar problem for the Navy. Interested faculty and students met biweekly for two quarters for a seminar in Categorical Data Analysis. In this seminar we discussed issues (such as the computational and theoretical problems of very large but sparse data sets) motivated primarily by DoD data. Reimbursable funds from USAREC have been secured to study DEP losses and several other potential funding sources have been identified. Professor Whitaker has also continued research on the two sample problem with ordinal responses, focusing on the small sample problem.

PUBLICATIONS: Sohn, S.Y., "An Investigation of the Statistical Relationship Between 345KV Transmission Line Length and the Outage Rate," International Journal of ROSE, to appear April 1994.

Read, R.R., "Performance Review of the Officer Rate Generator," Ver. 1.0, NPS Technical Report NPS-OR-93-002, October 1992.

OTHER: Read, R.R., "Descriptive Models of Monthly Officer Attrition," NPS Technical Report, forthcoming.

Read, R.R. and Whitaker, L.R., "A Data Analysis of Success in OCS, the Use of ASVAB Waivers, and Race, NPS Technical Report NPS-OR-93-013, September 1993.

Professor Smyth from the University of Queensland gave a seminar on "Gamma mixtures of Poissons," and has been invited for an extended visit in 1994. He will give a seminar series in Generalized Linear Models with a focus on those with categorical responses. Professor Whitaker has two papers in progress on the small sample ordinal data problem.

Vales, J., LT, USN, "Estimating Conditional Probabilities of Losses in the Delayed Entry Program," Master's Thesis, expected March 1994.

Mattos, R., "US Navy's Delayed Entry Program Effects of it's Length on DEP

Loss and First Term Attrition," Master's Thesis, expected March 1994.

THESES DIRECTED: Beagle, R., LT, USN, "The Navy's Search for a Few Good Women: Analysis of a Direct Mail Campaign," Master's Thesis, September 1993.

Lian, T.T., "Application of Logistic Regression and Survival Analysis to the study of CEP, Manpower Performance, and Attrition," Master's Thesis, September 1993.

DOD KEY TECHNOLOGY AREA: Other.

KEYWORDS: Categorical Data Analysis, Generalized Linear Models, Logistic Regression.

SYSTEM EFFECTIVENESS MODELS-NATO SEASPARROW

W.M. Woods, Professor

Department of Operations Research

Sponsor and Funding: Naval Warfare Aircraft Center (NWAC)

OBJECTIVE: Work on this project in FY92 resulted in system effectiveness equations for the NATO Seasparrow Surface Missile System. The use of these equations require estimates of probabilities that a specific target (type, range, altitude, speed) will be killed when two NATO Seasparrow missiles are fired against it with known errors in a specific set of the missile parameters at time of launch. These estimates must be obtained using existing six DOF computer missile fly-out simulations and end-game analysis. A portion of the effort in FY93 was devoted to evaluating the capability to perform these simulations at NPS using existing missile fly-out simulations in an NPS simulation laboratory. Although NPS has the six DOF fly-out software approved by the NATO Programs Office, some special expertise is needed to do some of the end-game analysis that may not reside at NPS. Discussions were held with Naval Surface Warfare Center (NSWC) personnel at China Lake, to assess the feasibility of NPS students performing these fly-out simulations at NPS and perhaps combining efforts with NSWC to do special end-game analysis if needed. Such a combined effort is needed in order to do the required simulations, because budget cuts in the NATO Seasparrow Program prohibit the support for these simulations at Navy labs. The effort is still in progress and, if resolved, should lead to a highly valuable student thesis.

During FY93, the principle investigator served on the Technical Advisory Group (TAG) for the Troubled

System Process, a program jointly managed by the CINCPACFLT AND CINCLANTFLT. He attended two two-day meetings at the Naval Warfare Center, Corona, California. A final report was given on the evaluation of the roll up procedure used to compute the Equipment Operating Capability (EOC) for major systems using Pre-EOC values on sub systems, down to three indented levels below the system level. This roll-up procedure was developed by Vitro Corporation over ten years ago and had been validated by several contractors and universities. In my review, it was found to contain a basic flaw in the way it accounted for "redundant" components. Final recommendations were made to modify elements of the TSP process to correct the discovered weakness.

A report was developed and delivered that reviewed a proposed extension of the TSP roll-up algorithm to the Battlegroup level using base line pre-EOC values for ships.

A methodology was developed to assess the impact on the system EOC of a no-test on some of its critical components during the Combat System Readiness Tests (CSRT). These no-test reports are usually correctly shortly after completion of the CSRT tests, but when counted as no-test give misleading results in the System EOC.

DOD KEY TECHNOLOGY AREA: Other.

KEYWORDS: Operational Readiness, System Effectiveness.

**DEPARTMENT
OF
OPERATIONS RESEARCH**

**1993
Faculty Publications
and Presentations**

JOURNAL ARTICLES

Aras, G., Whitaker, L.R., and Wu, Y.H., "Sequential Nonparametric Estimation of an Optimal Age Replacement Policy: A Simulation Study," Communications in Statistics: Simulation and Computation, Vol. 22, 1993.

Bradley, G.H., Brown, G., and Vassiliou, A., "Optimizing Disaster Relief: Real-Time Operational and Tactical Decision Support," Naval Research Logistics, Vol. 40, pp. 1-23, 1993.

Bradley, G.H. and Wood, K., "Deterministic Network Interdiction," Mathematical and Computer Modeling, Vol. 17, pp. 1-18, 1993.

Bradley, G.H., Wood, K., and DeWolfe, D., "Setting Military Reenlistment Bonuses," Naval Research Logistics, Vol. 40, pp. 143-160, 1993.

DeWolfe, D., Stevens, J., and Wood, K., "Setting Military Reenlistment Bonuses," Naval Research Logistics, Vol. 40, pp. 143-160, 1993.

Gaver, D.P., Morrison, J.A., and Silveira, R., "Service-Adaptive Multi-Type Repairman Problems," SIAM Journal of Applied Math, Vol. 53, No. 2, pp. 459-470, April 1993.

Sohn, S.Y. and Thomas, G., "Estimating the Geographic Extent of Part-Time Labor Market: US Army Reserves," Decision Sciences, Vol. 24, No. 2, pp. 479-492, 1993.

Wood, K., "Deterministic Network Interdiction," Mathematical and Computer Modeling, Vol. 17, pp. 1-18, 1993.

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Bailey, M.P., Callahan, A.J., and Bowden, J., "Managing Ship Performance of Naval Gunfire Support using Statistical Process Control," in Proceedings of the 1993 ADPA Conference on Statistical Process Control, (expanded version submitted to Military Operations Research).

Bailey, M., Dorko, M., Kemple, W., Schultz, R., and Sovereign, M., "Testing, Evaluating, and Enhancing NATO Tactical Communications Schemes," in Proceedings of the Winter Simulation Conference, 1993.

Brutzman, D.P., LCDR, USN, (Ed), "Video Proceedings of the Eight International Symposium on Unmanned Untethered Submersible Technology," University of New Hampshire, Durham, NH, 27-29 September 1993.

Dryer, D., Larson, H., Kemple, W., and Lamont, R., "Enhancing Tactical Direct Fire Synchronization Measures," in Proceedings of the 24th Symposium on the Interface: Computing Science and Statistics, Interface Foundation of North America, pp. 283-287, 1993.

Gaver, D.P., "Modeling and Simulation in the Military: Statistical Issues and Opportunities," in Proceedings of the Thirty-Eight Conference on the Design of Experiments in Army Research Development and Testing, Army Research Office Report 93-2, 1993.

Kemple, W., Larson, H., Lamont, R., Lawphongpanich, S., Nelson, M., Dryer, D., and Fernan, J., "Toward Battlefield Visualization," in Proceedings of the Statistical Graphics Section, American Statistical Association 1992 Annual Meeting, American Statistical Association, pp. 89-94, 1993.

Kemple, W., Dryer, D., Fernan, J., Lamont, R., Larson, H., and Nelson, M., "Graphical Indicators of Battlefield Performance," in Proceedings of the 25th Symposium on the Interface, University of California, Berkeley, 1993.

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CONFERENCE PRESENTATIONS

Bailey, M.P., "Implementation of Reliability Goal Determination Methods in Procurement and Surveillance," JMEMS-Methodology Working Group, Dahlgren, VA, September 1993.

Bailey, M.P., Callahan, A.J., and Bowden, J., "Managing Ship Performance of Naval Gunfire Support Using Statistical Process Control," ADPA Conference on Statistical Process Control, 1993.

Bailey, M., Dorko, M., Kemple, W., Schultz, R., and Sovereign, M., "Testing, Evaluating, and Enhancing NATO Tactical Communications Schemes," Winter Simulation Conference, Los Angeles, CA, December 1993.

Bohn, D., Schmitz, E., and Lawphongpanich, S., "Station Location Model," JMARC Annual Symposium, Orlando, FL, 9-11 March 1993.

Bradley, G.H., "Optimization of Capital Portfolios in the Telephone Industry," Management Science Seminar, University of Chicago, IL, 13 May 1993.

Brutzman, D.P., LCDR, USN, "Unmanned Submersible Technology," Eight International Symposium, University of New Hampshire, Durham, NH, 27-29 September 1993.

Dell, R.F. and Farmer, R., "Developing Schedules for Coast Guard District Cutters," National Meeting of the Operations Research Society of America and The Institute of Management Science, 16-19 May 1993.

Dell, R.F., Bulfin, R.L., and Kunzman, D.S., "Determining Optimal Instructor Levels at the Defense Language Institute," Foreign Language Center, National Meeting of the Operations Research Society of America and the Institute of Management Science, 31 October - 3 November 1993.

Dryer, D., Larson, H., Kemple, W., and Lamont, R., "Enhancing Tactical Direct Fire Synchronization Measures," 24th Symposium on the Interface: Computing Science and Statistics, Interface Foundation of North America, 1993.

Fernan, J., Kemple, W., and Larson, H., "Nonlinear Battle Analysis Visual Display Indicators," Working Group 33, 61st Military Operations Research Symposium, Wright-Patterson Air Force Base, Dayton, OH, June 1993.

Gaver, D.P., "Modeling and Simulation in the Military: Statistical Issues and Opportunities," Thirty-Eighth Conference on the Design of Experiments in Army Research Development and Testing, 1993.

Gaver, D.P. and Jacobs, P.A., "Statistical Issues in Combining Information," Statistics Seminar, University of Queensland, Brisbane, Australia, 26 November 1993.

Gaver, D.P., Jacobs, P.A., and Parry, S.H., "Modelling Sensor Effects" Interim Progress Review, The Joint Staff J-8, 28 October 1993.

Gaver, D.P., Jacobs, P.A., and Carpenter, R.L., "Preliminary Probability Models for Effects of Toxins in Organs," ORSA/TIMS Joint National Meeting, Phoenix, AZ, 31 October - 3 November 1993.

Gaver, D.P. and Jacobs, P.A., "An Exploratory Stochastic Model for Toxic Effects on Cells," National Institute of Environmental Health Sciences," Research Triangle Park, NC, 29 September 1993.

Gaver, D.P. and Jacobs, P.A., "Quantitative Analysis of Bioassay Data from Different Biomonitoring Test Systems (BTS)," Army Biomedical Research and Development Project Review, 26-27 October 1993.

Gaver, D.P., invited discussion of G.S. Bayard (EPA), "Combining Epidemiological Studies for Human Health Risk Assessment: Passive Smoking and Dioxin," U.S.E.P.A. and National Institute of Statistical Sciences Workshop on Statistical Methods for Combining Environmental Information, Chapel Hill, NC, 27 September 1993.

Gaver, D.P., Coffman, E.G., Jr., Jacobs, P.A., and Wright, P.E., "Adaptive Packing" Applied Probability in Engineering, Computer and Communication Sciences," Paris, France, 16-18 June 1993.

Gaver, D.P., Youngren, M., and Jacobs, P.A., "Perception Updating in the Future Theater Level Combat Model," Sensor Modeling Workshop, AMSAA, Aberdeen Proving Ground, MD, 25-26 May 1993.

Hughes, W.P. Jr., "Naval Forces in Joint Littoral Warfare," 61st MORS Symposium Working, 22 June 1993.

Kemple, W., Dell, R., and Tovey, C., "Tabu Search and Simulated Annealing Applied to the Stratigraphic Correlation Problem," Seminar in Operations Research, Naval Postgraduate School, February 1993.

Kemple, W., Dell, R., and Tovey, C., "Heuristic Selection Through Experimentation: Tabu Search and Simulated Annealing Applied to the Stratigraphic Correlation Problem," University of California, Riverside, Statistics Department Colloquium, April 1993.

Kemple, W., Dryer, D., Fernan, J., Lamont, R., Larson, H., and Nelson, M., "Graphical Indicators of Battlefield Performance," 25th Symposium on the Interface, San Diego, CA, March 1993.

Kemple, W., "An Evaluation Framework," Military Operations Research Society C3IEW Workshop, Naval Postgraduate School, March 1993.

Marshall, K.T., "Influence Diagrams and the Value of Information in Decision Modeling," invited tutorial, 61st Military Operations Research Society Symposium (MORS), AFIT, 22-24 June 1993.

Marshall, K.T., "The Analytic Hierarchy Process (AHP): How it Works, and Associated Problems," Department of Operations Research Seminar, Naval Postgraduate School, 17 November 1993.

Read, R.R., "Outline of a Machine that Sorts in Linear Time," Seminar presentation, Department of Electrical Engineering, U.S.C., 31 August 1993.

Schrady, D.A., "Battle Group Logistic Support System," SPAWAR for SPAWAR, N4 and N6 Personnel, (Software Demonstration), 28 July 1993.

Schrady, D.A., "Battle Group Logistic Support System," Secure Tactical Data Network-4 Exercise, (Software Demonstration), NRaD, San Diego, CA, 1-14 September 1993.

Schrady, D.A., "Battle Group Logistic Support System," JMCIS Requirements Working Group, (Software Demonstration), Dam Neck, VA, 18-20 October 1993.

Schrady, D.A., "Battle Group Logistic Support System," Naval Tactical Command System Support Meeting, (Software Demonstration), North Island, San Diego, CA, 7-8 December 1993.

Schrady, D.A., "Battle Group Logistic Support System," Logistics Wargame 94, Naval War College, (Software Demonstration), Newport, RI, 10-14 January 1993.

Sohn, S.Y., "Estimating the Shelf-Life of Ammunition Stockpile Under Step-Stress," ASA Joint Statistical Meeting, San Francisco, CA, August 1993.

Sohn, S.Y., "A Statistical Analysis of Ammunition Stockpile Deterioration Under Step-Stress," ORSA/TIMS Joint National Meeting, Chicago, IL, May 1993.

Youngren, M., Gaver, D.P., Jacobs, P.A., and Parry, S.H., "Future Stochastic Theater Level Combat Modeling," Working Group 14, Military Operations Research Society, Dayton, OH, June 1993.

Washburn, A. and Mullens, C., LT, USN, "Tactical Mine Countermeasures Planning," American Defense Preparedness Association Meeting, Naval Postgraduate School, 23-25 May 1993.

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Aras, G. and Whitaker, L.R., "Some Sequential Procedures to Estimate the Optimal Age Replacement Policy," Probability and Statistics, Narosa Publishing House, 1993.

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Bradley, G.H., Brown, G., and Olson, M., "Elastic Modeling with the X-System and GAMS," User's Manual, June 1993.

Kemple, W.G., "TACFONE-NATO," an Object Oriented Simulation Model, with User's Manual, delivered to the Joint Interoperability Engineering Office, Fort Monmouth, NJ, 1993.

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Brown, G. and Olson, M., "Dynamic Factorization in Large-Scale Optimization," NPS Technical Report NPS-OR-93-008, May 1993.

Brown, G., Coulter, D., and Washburn, A., "Sortie Optimization and Munitions Planning," NPS Technical Report NPS-OR-93-011, May 1993.

Carpenter, R.L., Gaver, D.P., and Jacobs, A., "An Exploratory Model for Toxic Effects on Cells," NPS Technical Report NPS-OR-93-014, September 1993.

Cooper, C. and Read, R., "Range Calibration Studies Interim Report," NPS Technical Report NPS-OR-93-012, May 1993.

Dell, R.F., Kunzman, D.S., and Bulfin, R.L., "Determining Optimal Instructor Levels at the Defense Language Institute," NPS Technical Report NPS-OR-93-022, December 1993.

Dell, R.F., Rosenthal, R.E., and Baig, S., "Peacetime Rotation of Pakistan Army Units," NPS Technical Report NPS-OR-93-023, November 1993.

Gaver, D.P. and Jacobs, P.A., "Asymptotic Properties of Stochastic Greedy Bin-Packing," NPS Technical Report NPS-OR-93-017, November 1993.

Gaver, D.P. and Jacobs, P.A., "A Comparison of Predictors for First-Guess Wind Speed Errors," NPS Technical Report NPS-OR-93-020, December 1993.

Larson, H. and Kemple, W., "Graphical Displays of Synchronization of Tactical Units," NPS Technical Report NPS-OR-93-010, March 1993.

Marshall, K.T., Conner, G.W., and Ehlers, M.A., "Countering Short Range Ballistic Missiles," NPS Technical Report NPS-OR-93-009, January 1993 (submitted for publication in Military Operations Research).

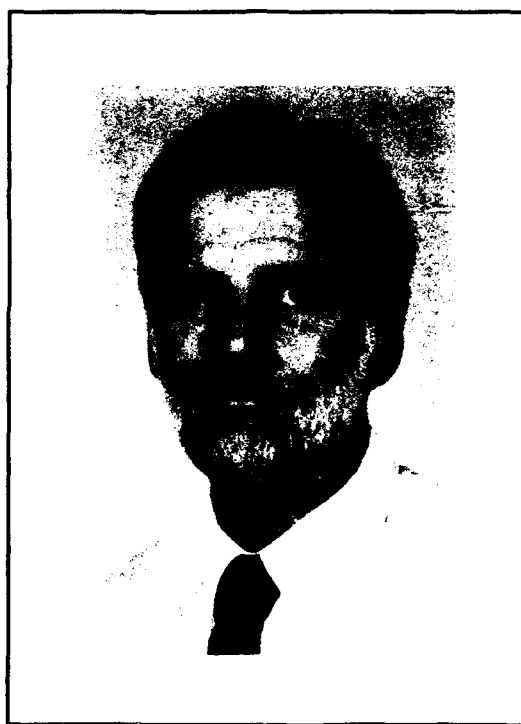
Marshall, K.T., "The Naval Postgraduate School and Unrestricted Line Officer Graduate Education," Naval Postgraduate School Report, October 1993.

Read, R.R. and Whitaker, L.R., "A Data Analysis of Success in OCS, the Use of ASVAB Waivers, and Race," NPS Technical Report NPS-OR-93-013, September 1993.

Schrad, D.A., "Carrier Strike Ordnance Planning Factors: Desert Storm Experience, (U)" NPS Technical Report NPS-OR-93-021, December 1993.

Sohn, S.Y., "Monitoring Declining Quality of Ammunition Stockpile Under Step-Stress," NPS Technical Report NPS-OR-93-016, December 1993.

**DEPARTMENT
OF
PHYSICS**



**William B. Colson
Chairman**

DEPARTMENT OF PHYSICS

The following thirty-four research summaries describe projects which were carried out under the direction of faculty members in the Physics Department during FY93. They span a broad range from basic research into the production of light by high amplitude sound fields (sonoluminescence) to applied topics such as an analysis of fleet weapons systems like the Phalanx gun and infrared technology support for the Aegis program. Although a good deal of theoretical analysis is employed in all of these projects, almost all are distinguished by the fact that they included laboratory and/or field experiments and they produce physical "hardware". All of the research programs involve our officer/students whose contributions to these efforts are documented in their Master's theses.

BASIC RESEARCH IN SONOLUMINESCENCE

A.A. Atchley, Associate Professor

Department of Physics

Sponsor and Funding: Naval Postgraduate School

OBJECTIVE: This project is an experimental investigation of the properties of picosecond sonoluminescence, emitted by single gas bubbles levitated in water/glycerin solutions by an acoustic standing wave. The emphasis of this basic research project is on measuring the spectrum of the emitted light, the size of the bubble during light emission, the duration of the emission, and the periodicity of the emission.

SUMMARY: The main conclusions from the spectral measurements are: the radiated energy decreases as the glycerin concentration increases; the peak of the spectrum shifts to longer wavelengths as the glycerin concentration increases, indicating that the bubble is effectively cooler; and the fitted blackbody temperature for emission from water is ~16 000 K while that from glycerin solutions is ~10 000 K. In order to better understand sonoluminescence, it is desirable to know the radius of the bubble as a function of time. It is particularly important to know the radius of the bubble near the time of emission. Such measurements have been performed using a pulsed laser, Mie scattering technique. The results indicate that the bubble may reach a radius of approximately 3 μ m at the time of SL emission. The maximum bubble wall velocity is estimated to be approximately 130 m/s. Direct imaging of the luminescing bubble with a CCD camera yields similar results. Measurements of the periodicity of the emission showed that period doubling, quasiperiodicity and chaotic behavior were observed under certain drive parameters. Measure-

ments of the duration of the emission are still under analysis.

PUBLICATIONS: Atchley, A. A., "Review of Recent Advances in Synchronous Picosecond Sonoluminescence," Advances in Non-linear Acoustics, H. Hobaek, ed., World Scientific, River Edge, NJ, 1993.

Lentz, J., Atchley, A.A., Gaitan, D. F., and Maruyama, X.K., "Mie Scattering from a Sonoluminescing Bubble," Advances in Nonlinear Acoustics, H. Hobaek, ed., World Scientific, River Edge, NJ, 1993.

Carlson, J.T., Lewia, S.D., Atchley, A.A., Gaitan, D.F., Maruyama, X.K., Lowry, M.E., Moran, M.J., and Sweider, D.R., "Spectra of Picosecond Sonoluminescence," Advances in Non-linear Acoustics, H. Hobaek, ed., World Scientific, River Edge, NJ, 1993.

Holt, R.G., Gaitan, D.F., Atchley, A. A., and Holzfuss, J., "Sonoluminescence in a Single Bubble: Periodic, Quasiperiodic, and Chaotic Light Source," in Proceedings of the 2nd Experimental Chaos Conference, Arlington, VA, 1993.

Holzfuss, J.R., Holt, G., Gaitan, D. F., and Atchley, A.A., "Sonolumineszenz Oszillierender Blasen: Untersuchungen zu einem neuen Phänomen" Fortschritte der Akustik - DAGA '93, Bad Honnef: DPG GmbH, 1993.

CONFERENCE PRESENTATIONS: Atchley, A.A. Carlson, J.T., Gaitan, D.F. Lewia, S.D., Maruyama, X.K., Lowry, M.E., Moran, M.J., and Sweider, D. R., "Sonoluminescence Spectra," 125th

Meeting of the Acoustical Society of America, Ottawa, Canada, May 1993, Journal of the Acoustical Society of America, Vol. 93, No. 4, Pt. 2, p. 2383(A), 1993.

Gaitan, D.F., Holt, G., and Atchley, A.A., "Investigation of Periodicity of Sonoluminescing from a Single Bubble," 124th Meeting of the Acoustical Society of America, New Orleans, LA, October 1992, Journal of the Acoustical Society of America, Vol. 92, No. 4, Pt. 2, p. 2452(A) 1992.

Atchley, A.A., "Review of Recent Advances in Synchronous Picosecond Sonoluminescence," 13th International Symposium on Nonlinear Acoustics, Bergen, Norway, July 1993.

Lentz, W.J., Atchley, A.A. Gaitan, D. F., and Maruyama, X.K., "Mie Scattering from a Sonoluminescing Bubble," 13th International Symposium on Nonlinear Acoustics, Bergen, Norway, July 1993.

Carlson, J.T., Maruyama, X.K., Lewia, S.D., Atchley, A.A., Gaitan, D.F., Lowry, M.E., Moran, M. J., and Sweider, D. R., "Spectra of Picosecond Sonoluminescence," 13th International Symposium on Nonlinear Acoustics, Bergen, Norway, July 1993.

Atchley, A.A., Maruyama, X.K., Carlson, J.T., Gaitan, D.F., Lewia, S.D., Lowry, M.E., Moran, M. J., and Sweider, D.R., "Sonoluminescence Spectra," 125th Meeting of the Acoustical Society of America, Ottawa, Canada, May 1993, Journal of the Acoustical Society of America, Vol. 4, Pt. 2, 2383(A), 1993.

THESES DIRECTED: Carlson, L., LT, USN, "Visible Spectrum of Stable Sonoluminescence," Master's Thesis in Physics, December 1992.

Lewia, S., LCDR, USN, "Spectra of Stable Sonoluminescence," Master's Thesis in Physics, December 1992.

OTHER: Holt, R.G., Gaitan, D.F., Atchley, A.A., and Holzfuss, J., "Chaotic Sonoluminescence," submitted to Physical Review Letters, 1993.

DOD KEY TECHNOLOGY AREA: Energy Conversion.

KEYWORDS: Sonoluminescence, Acoustics, Cavitation, Nonlinear Dynamics, Basic Research.

BASIC RESEARCH IN THERMOACOUSTIC HEAT TRANSPORT

A.A. Atchley, Associate Professor

Department of Physics

Sponsor and Funding: Office of Naval Research

OBJECTIVE: The long term goal of this research is to develop a thorough understanding of thermoacoustic phenomena. The investigations involve both heat pumps and prime movers.

SUMMARY: Our major research efforts in FY 1993 were concentrated in five areas: 1) an analysis of the initial buildup of oscillations in thermoacoustic prime movers; 2) an investigation of stability curves for a thermoacoustic prime mover; 3) initial measurements of the velocity field in thermoacoustic engines using laser Doppler anemometry; 4) measurements of heat exchanger performance in a thermoacoustic prime mover; and 5) a preliminary investigation of heat driven refrigerators. In addition to these areas, FY 1993 research efforts also included a collaborative experiment on traveling wave thermoacoustic effects. The results of these investigations are detailed in the publications listed below.

PUBLICATIONS: Gaitan, D.F. and Atchley, A.A., "Finite Amplitude Standing Waves in Harmonic and Anharmonic Tubes," Journal of the Acoustical Society of America, Vol. 93, pp. 2489-2495, 1993.

Atchley, A.A., "Annual Summary of Basic Research in Thermoacoustic Heat Transport: 1992," NPS Technical Report NPS PH-93-006, November 1992.

CONFERENCE PRESENTATIONS: Atchley, A.A., "Standing Wave Analysis of the Low Amplitude Performance of a Thermoacoustic Prime Mover," 123rd Meeting of the Acoustical Society of

America, Salt Lake City, UT, May 1992, Journal of the Acoustical Society of America, Vol. 91, No. 4, Pt. 2, p. 2396(A), 1992.

Gaitan, D.F. and Atchley, A.A., "Finite Amplitude Standing Waves in Harmonic and Anharmonic Closed Tubes," 123rd Meeting of the Acoustical Society of America, Salt Lake City, UT, May 1992, Journal of the Acoustical Society of America, Vol. 91, No. 4, Pt. 2, p. 2330(A), 1992.

THESES DIRECTED: Kuo, F.M., "Stability Curves for a Thermoacoustic Prime Mover," Master's Thesis Engineering Acoustics, June 1993.

Che, C., CDR, Taiwan Navy, "Investigation of a Thermoacoustic Muffler," Master's Thesis, Engineering Acoustics, December 1992.

OTHER: Atchley, A.A. and Kuo, F.M., "Stability Curves for a Thermoacoustic Prime Mover," accepted for publication in Journal of the Acoustical Society of America, expected publication date March 1994.

Atchley, A.A., "Analysis of the Initial Buildup of Oscillations in a Thermoacoustic Prime Mover," accepted for publication in Journal of the Acoustical Society of America, expected publication date March 1994.

DOD KEY TECHNOLOGY AREA: Environmental Effects, Electronic Devices.

KEYWORDS: Thermoacoustics, Acoustics, Heat Engine, Prime Mover, Basic Research.

ABSORPTION OF SOUND BY ANISOTROPIC NOISE

A. Atchley, Associate Professor

B. Denardo, Research Assistant Professor

A. Larraza, Research Assistant Professor

Department of Physics

Sponsor and Funding: Naval Postgraduate School

OBJECTIVE: This project deals with experimental and theoretical studies of the nonlinear interactions of sound with anisotropic noise. Specifically, the experimental determination of the attenuation of a signal by a highly anisotropic noise source. Applications to the shallow water acoustic environment are made.

SUMMARY: In the presence of high intensity broad band noise, a small signal attenuates due to nonlinear interactions with the noise. If the noise is isotropic, the attenuation is exponential, $\exp(-ax)$, where x is the distance from the source. One might think that in typical systems the attenuation of a signal due to viscous and thermal losses would dominate the attenuation due to interaction with noise. However, this is not true for underwater sound propagation at acoustic frequencies below 10^4 Hz (which is the frequency range of interest in Navy applications). In this case, the attenuation of an acoustic signal due to the ambient noise energy ($\sim 2 \times 10^{-4}$ erg/cm³) dominates viscous and thermal losses. For shallow water acoustic propagation, bottom friction and topography may be the main cause for sound attenuation. However, these can cause the noise spectral distribution to be anisotropic (i.e., to depend upon direction). In the limiting case of interaction with noise in one dimension, the attenuation coefficient has been predicted to be a

linear function of position; that is, the amplitude of the signal attenuates as a gaussian, $\exp(-bx^2)$, where b depends on the total integrated noise, and is independent of the details of noise spectral distribution. Although it is not known at present, even a small amount of noise anisotropy may give rise to a gaussian component to the attenuation of a signal. Because the gaussian will necessarily dominate the exponential for sufficiently large distances, anisotropic ambient noise can play an important role in the attenuation of a shallow water acoustic signal.

CONFERENCE PRESENTATIONS: Denardo, B., "Nonlinear Waves: Self-Localized Structures and Absorption of Sound by Anisotropic Noise," Physics Department and National Center for Physical Acoustics colloquium, University of Mississippi, University, MS, 5 November 1992.

Larraza, A., Denardo, B., Atchley, A.A., and Dorff, S., "Absorption of Sound by Noise in One Dimension," Journal of the Acoustical Society of America, Vol. 93, Pt. 2, 4pPA3, 1992.

DOD KEY TECHNOLOGY: Environmental Effects.

KEYWORDS: Nonlinear waves, Random Waves, Shallow Water Ocean Acoustics.

**EXPERIMENTAL INVESTIGATION OF THE SCATTERING OF
UNDERWATER SOUND FROM A POROUS SOLID SPHERE**

S.R. Baker, Associate Professor

Department of Physics

Sponsor: Naval Coastal Systems Station

Funding: Naval Postgraduate School

OBJECTIVE: The objective is to experimentally validate a theory developed by scientists at the Naval Coastal Systems Station for the scattering of underwater sound from a porous solid sphere. This is a new project.

SUMMARY: Drs. Raymond Lim and Steve Kargl of the Naval Coastal Systems Station have developed a theory for the scattering of elastic waves from a fluid-filled porous solid obstacle embedded in a fluid-filled porous solid host. Their theory employs the Biot theory for the propagation of elastic waves in a fluid-filled porous solid and the T-matrix method for the multiple scattering of waves. The theory has potential application to the detection of mine-like objects buried in sediment.

Professor Baker initiated a project in FY93 to experimentally validate Lim and Kargl's theory. As a first test, experimental measurements of the scattering of underwater sound from a porous solid sphere were compared to predictions of Lim and Kargl's theory. To the best of our knowledge, such measurements have not been reported previously.

Porous solid sphere samples were obtained of nominal diameter 2 inches, one composed of 100 micron and the other composed of 500 micron

nominal diameter bonded glass beads. Cylindrical samples manufactured at the same time as the spherical samples were also obtained. Physical properties such as porosity, permeability, and shear modulus were measured for the cylindrical samples. The values obtained for the cylindrical samples were assumed for the spherical samples in calculating the expected acoustic scattering. Underwater acoustic scattering measurements were made on the spherical samples as a function of angle and frequency in the underwater acoustic tanks at NPS. The range of frequency covered was approximately 30 kHz to 150 kHz. The experimental results were in rough order-of-magnitude agreement with the theoretical predictions, but showed practically none of the lobe structure as a function of angle predicted by the theory. The investigation continues.

THESIS DIRECTED: Huskey, Ted, LT, "Scattering of Underwater Sound from a Porous Solid Sphere," Master's Thesis in Systems Technology (ASW), September 93.

DOD KEY TECHNOLOGY: Other.

KEYWORDS: Underwater Acoustics, Porous Media Acoustics, Biot Theory, T-matrix.

**TRANSDUCER ELEMENT INTERACTION IN DENSELY-PACKED
VOLUMETRIC ACTIVE SONAR ARRAYS**

S.R. Baker, Associate Professor
Department of Physics

Sponsor: Naval Undersea Warfare Center

Funding: Naval Postgraduate School and
Naval Undersea Warfare Center

OBJECTIVE: The objective is to quantify the limitations of numerical models of array element interaction. This project is a new companion to a project in which the T-matrix method is being applied to model low frequency active array performance. The present investigation involves laboratory experiments as well as numerical modeling.

SUMMARY: Experiments were conducted in FY93 by Prof. Baker and student LT Doug Cuthbert using small flexural disk sonar transducers instrumented with surface mounted strain gages. In-air measurements were made of the surface normal velocity distribution over each face of two transducers using a laser doppler vibrometer and of the surface strain at the center of each disk. Over the frequency range of interest it was found that, for these transducers, the surface strain at the center uniquely determined the surface normal velocity distribution over the entire disk. In-water measurements were made of the surface strain at the center of each face of a pair of transducers while only one was driven for separation distances of $1/2$, 1 , $1-1/2$, and 2 disk radii.

Visiting French Naval officer/

engineer CAPT Jean-Marc Cortambert has continued these studies following LT Cuthbert's graduation. CAPT Cortambert has built a finite-element model of the flexural disk transducer for use with the ATILA code, and has used the code to compute the acoustic field for a pair of such transducers in close proximity to one another. He has also made laboratory measurements to validate the computations. His early results were reported at a meeting of the Acoustical Society of America.

CONFERENCE PRESENTATION: Cortambert, J.-M. and Baker, S.R., "Understanding Coupling Between Flexural Disk Transducers from Near Field Measurements," Journal of the Acoustical Society of America, Vol. 94, No. 3, Pt. 2, p. 1832, 1993.

THESIS DIRECTED: Cuthbert, Douglas Lee, LT, "Experimental Determination of the Surface Displacement of a Small Flexural Disk Sonar Transducer from Surface Strain Measurements," Master of Science Engineer Acoustic and Master of Science in Systems Technology (ASW), April 93.

DOD KEY TECHNOLOGY: Sensors.

KEYWORDS: Underwater Acoustics, Sonar, Array, and Active.

FIBER OPTIC SENSOR SYSTEMS

D.A. Brown, Research Assistant Professor

R. Keolian, Assistant Professor

Department of Physics

Sponsor and Funding: Program Executive Office, Undersea Warfare,
Advanced Systems and Technology Office

OBJECTIVE: The goal of this project was to develop low cost alternative approaches to fiber optic acoustic sensor systems for hull mounted arrays. This includes improvements in the development of acceleration canceling acoustic sensors and demonstration of new low cost high dynamic range interferometric demodulation systems and a new multiplexing scheme that is compatible with 3x3 coupler terminated fiber optic sensors.

SUMMARY: We demonstrated a low cost sonar system for submarine Wide-Aperture Arrays. The NPS system uses push-pull sensors, 3x3 coupler based passive demodulation, and an amplitude modulated frequency multiplexing scheme. We demonstrated a new software based demodulator producing detection thresholds of $0.2\mu\text{rad}/\sqrt{\text{Hz}}$, the best ever reported in the open literature. We demonstrated a software demodulator that removes the need for most of the inboard electronics needed with other demodulation schemes in addition to the fiber optic sensors which remove all of the wet end electronics.

We also analyzed flow noise data from a test of an NPS acceleration canceling, flow noise averaging, hydrophone installed on KAMLOOPS, the Navy's quarter scale submarine used for "pop-up" tests at Bayview, Idaho. The sponsor also funded a collaborative research project with Brown University in which the Principal Investigator studied the theory and

fabrication of fiber optic fused biconical couplers and fiber optic Bragg gratings. The new fiber optic Bragg gratings are particularly interesting since they can be unobtrusively "written" into standard telecommunications fiber and then used directly as acoustic sensors or as narrowband mirrors for multiplexing applications.

PUBLICATION: Reid, G. and Brown, D.A., "Multiplex Architecture for 3x3 Based Fiber-Optic Sensors," in Distributed and Multiplexed Fiber Optic Sensors, Society for Photo-Optical Instrumentation Engineers (SPIE), p. 2071, September 1993.

CONFERENCE PRESENTATIONS: Brown, D.A., "Characterization of Viscoelastic Materials Using the resonant Modes of a Free-Free Bar," Invited talk, published abstract, The Journal of the Acoustical Society of America, Vol. 94, No. 3, Pt. 2, September 1993.

Brown, D.A., Netzorg, G.D., White, B., Kapolka, D., Gardner, D.L., and Garrett, S.L., "A Planar Eight Element Flexural Disk Fiber Optic Acoustic Sensor," published abstract in The Journal of the Acoustical Society of America, Vol. 95, Supplement 4, 125th meeting, Ottawa, May 1993.

Brown, D.A., "Dual-Use Fiber Optic Sensors," 1993 NUWC R&D Symposium in conjunction with the American Defense Preparedness Association, Undersea Warfare Systems Division, Conference, Newport, RI, November 1993.

Brown, D.A., Keolian, R.M., Gardner, D.L., and Garrett, S.L., "Fiber Optic Interferometric Hydrophones and demodulators," The American Defense Preparedness Association, Undersea Warfare Systems Division, Conference, Monterey, CA, May 1993.

Garrett, S.L. and Brown, D.A., "Thermo-Acoustic Counter Measures and High Dynamic Range Hydrophone Systems," The American Defense Preparedness Association - Undersea Warfare Systems Division - Conference, Monterey, CA, 1993.

THESIS DIRECTED: McGinnis, B.R., LT, USN, "Digital Demodulation of an Interferometric Signal," Master's Thesis in Electrical Engineering and Engineering Acoustics, June 1993.

PATENTS: Brown, D.A., "Flextensional Hydrophone," U.S. Patent No. 5, 211, 670, issued 18 May 1993.

Brown, D.A., Hofler, T., and Garrett, S.L., "Fiber Optic Flexural Disk Accelerometer," Patent filing fee paid, awaiting printing - December 1993, Navy Case 73054.

Hofler, T., Brown, D.A., and Garrett, S.L., "Fiber Optic Accelerometer with Centrally Supported Flexural Disk," Patent application, Navy case 75845, submitted 1993.

Brown, D.A. and Jakshau, G., "A Mechanical Device for Demonstrating Characteristics of Interferometric Signals," submitted June 1993.

OTHER: Investigator has submitted article, "Tuning Bragg Wavelength by Writing Gratings on Pre-Strained Fibers," Zhang, Q., Brown, D.A., Reinhard, L., Morse, T.F., Wang, J.Q., and Xiao, G., accepted for publication to appear in electronic Letters. Papers in progress include: "End Corrections for Mass and Stiffness Loaded Bars," "Dynamic Properties of Candidate Standard Materials for Viscoelastic Materials," "Measurement of the Elastic Properties of Polycarbonate," and technical reports, "Multiplexing Systems for Sonar Sensors" and "Fiber Optic Accelerometers for Hull Arrays."

DOD KEY TECHNOLOGY: Sensors.

KEYWORDS: Fiber Optic, Sensors, Interferometers, Demodulators, Multiplexing, and Hull Arrays.

REMOTE SENSING OF THE IONOSPHERIC E- AND F-LAYERS

D.D. Cleary, Associate Professor

Department of Physics

Sponsor and Funding: Naval Research Laboratory

OBJECTIVE: This is an ongoing research project with the objective of developing a simple technique for measuring global ionospheric electron densities from a space based platform. The short term goal of this project was to obtain ultraviolet spectra of the Earth's ionospheric dayglow. The long term objective is to identify ultraviolet atmospheric emissions that can be used to infer electron density profiles with the aid of photochemical and radiative transfer models.

SUMMARY: On 19 March 1992, we conducted the second successful rocket flight of the MUSTANG/HIRAAS experiment from the White Sands Missile Range, NM. The instrument package consisted of an NPS middle ultraviolet spectrograph (1800 - 3400 Å), and an NRL extreme ultraviolet spectrograph (500 - 1500 Å). UV spectra of the Earth's ionosphere were obtained between 100 and 320 km on both the upleg and downleg portions of the flight. The purpose of this experiment is to test a technique for ionospheric remote sensing. Based on theoretical calculations, the ionospheric electron density can be inferred by measuring the natural ultraviolet emissions from the Earth's thermosphere. The electron density predicted from these rocket observations will be compared with

ground based measurements of the electron density profile. During this period we will perform the complete analysis of the UV spectra, compare measured and inferred electron densities and prepare for the 3rd and final sounding rocket flight. In addition, we will prepare the new flight instrument for the ARGOS satellite.

PUBLICATIONS: Morgan, H.D., Seyoum, H.M., Fortna, J.E., Humm, D.C., Asfaw, A., and Cleary, D.D., "Total Photoabsorption Cross Section of Molecular Nitrogen Near 83.4 nm," Journal of Geophysics Research, Vol. 98, p. 7799, 1993.

Atkinson, J.D., and Cleary, D.D., "A Technique for Modeling Interference Patterns From Two-Beam Interferometers," accepted for publication, Computers in Physics, 1994.

CONFERENCE PRESENTATIONS: Cleary, D.D., Gnanalingam, S., McCoy, R.P., Dymond, K.F., and Eparvier, F.G., "Self-Absorption of the Nitric Oxide Y Bands," American Geophysical Union, Fall Meeting, 1993.

DOD KEY TECHNOLOGY: Environmental Effects.

KEYWORDS: Ionospheric Physics, Ultraviolet Spectroscopy.

**SIMULATIONS OF THE NONLINEAR
HOMOGENEOUS WHISTLER INTERACTION**

W.B. Colson, Professor
Department of Physics

Sponsor and Funding: Office of Naval Research

OBJECTIVE: Continuation of the development of a new simulation for the study of the amplification of Whistler Waves in the Earth's magnetosphere.

SUMMARY: Whistler Waves may be amplified by a distribution energetic electrons spiraling along magnetic field lines near the geomagnetic equator. Natural whistlers often dominate the VLF noise spectrum in the polar regions and limit over-the-horizon communications. The similarities between free electron lasers and whistlers have resulted in the formulation of several scaling relationships that were not previously known for Whistler Waves. Ampere's and Faraday's Laws are combined to form a new theory describing the evolution of the complex optical electric and magnetic fields with arbitrary amplitudes and phases. Traditional whistler amplification theory has started from Maxwell's wave equation assuming the optical electric and magnetic fields are equal in amplitude and orthogonal. A new theory is developed that shows how the optical fields remain equal and orthogonal in the presences of even the most intense driving currents.

PUBLICATIONS: Colson, W.B., "Amplification of the Optical Electric and Magnetic Fields Described by Ampere's and Faraday's Laws", accepted by Nu-

clear Instruments and Methods in Physics Research, 1993.

Colson, W.B., Gately, B., Caudle, D. L., and Sturgess, K., "Analogies Between the Free Electron Laser and Whistler Mode Amplification in the Magnetosphere," Nuclear Instruments and Methods in Physics Research, Vol. A331, pp. 522, 1993.

CONFERENCE PRESENTATIONS: Colson, W., "Analogies Between the Free Electron Laser and Whistler Mode Amplification," Stanford University Radio Science Seminar, Stanford, CA, 17 February 1994.

Colson, W.B., "Amplification of the Optical Electric and Magnetic Fields Described by Ampere's and Faraday's Law," Fifteenth International Free Electron Laser Conference, The Hague, The Netherlands, August 1993.

THESES DIRECTED: Sturgess, Keith A., LT, USN, "A Study of the Amplification of Laser and VLF Waves Using a Simple Pendulum Model," Ph.D. Dissertation in Physics, 1993.

DOD KEY TECHNOLOGY: Communications Networking, Environmental Effects, Other.

KEYWORDS: Whistler Waves, Magnetosphere, Ampere's Law, and Faraday's Law.

SHIPBOARD FREE ELECTRON LASERS

W.B. Colson, Professor

Department of Physics

Sponsor and Funding: Naval Postgraduate School

OBJECTIVE: Research is directed toward the technology required for a Shipboard Free Electron Laser weapon system.

SUMMARY: The study of the proposed experiment in Novosibirsk, Russia for the SELENE High Power Free Electron Laser (FEL), at the Naval Air Warfare Center, China Lake, CA is relevant because the accelerator technology provides the possibility for high-average power, and high wall-plug efficiency. The electron beam is recirculated several times through a compact the accelerator cavities to reduce FEL size and increase wall-plug efficiency.

PUBLICATIONS: Wallace, S.M., Colson, W.B., Neil, G.R., and Harwood, L., "Magnetic Field Error Measurement of the CEBAF (NIST) Wiggler Using the Pulsed Wire Method," Nuclear Instruments and Methods in Physics Research, Vol. A331, pp. 759, 1993.

Blau, J., Frost, D.J., and Colson, W.B., "Amplification of Short Optical Pulses in the Boeing APLE Amplifier," Nuclear Instruments and Methods in Physical Research, Vol. A331, pp. 645, 1993.

Blau, J., Wong, R.K., Quick, D., and Colson, W.B., "Three Dimensional Simulations of the Novosibirsk/SELENE FEL," accepted by Nuclear Instruments and Methods in Physics Research.

CONFERENCE PRESENTATIONS: Blau, J., Wong, R.K., Quick, D., and Colson, W.B., "Three Dimensional Simulations of the Novosibirsk/SELENE FEL," Fifteenth International Free Electron Laser Conference, The Hague, The Netherlands, August 1993.

Wong, R.K. and Colson, W.B., "Transverse Mode Effects in Free Electron Laser Oscillators," presented at the SPIE OE/LASE '94 Gas, Metal Vapor, and Free Electron Laser and Applications Conference, Los Angeles, CA, 26 January 1994.

Quick, D., Blau, J., Wong, R. K., and Colson, W.B., "Phase Space Simulations of the Novosibirsk/SELENE FEL," accepted by SPIE OE/LASE '94 Gas, Metal Vapor and Free Electron Laser and Applications Conference, Los Angeles, CA, 26 January 1994.

THESES DIRECTED: Sturgess, Keith, A., LT, USN, "A Study of the Amplification of Laser and VLF Waves Using a Simple Pendulum Model," Ph.D. Dissertation in Physics, 1993.

DOD KEY TECHNOLOGY: Propulsion and Energy Conversion, Other.

KEYWORDS: Free Electron Lasers, Ship Defense, and High Energy Laser.

FREE ELECTRON LASER FOR SHIP DEFENSE

W.B. Colson, Professor

Department of Physics

Sponsor and Funding: Office of Naval Research

OBJECTIVE: Research on high power Free Electron Lasers is used as a basis for developing a shipboard Free Electron Laser Weapon System.

SUMMARY: The proposed experiment for the SELENE high power Free Electron Laser (FEL), at the Naval Air Warfare Center, China Lake, CA, is driven by an RF accelerator that recirculates the electrons through the accelerator in order to reduce size and increase efficiency. The undulator is designed as an FEL klystron in order to reduce the optical power on the resonator mirrors. The klystron is followed by a high power radiator the starts from the enhance spontaneous emission from the bunched electron pulses.

PUBLICATIONS: Sturgess, K.A., LT, USN, Frost, J., and Colson W.B., "Short Pulse Evolution in the Boeing APPLE Oscillator," Nuclear Instruments and Methods in Physics Research, Vol. A331, pp. 650, 1993.

Quick, D., Blau, J., Wong, R.K., and Colson, W.B., "Phase Space Simulations of Electrons Bunching and Power Output in the Novosibirsk/SELENE FEL," accepted by Nuclear Instruments and Methods in Physics Research.

Wong, R.K., Clark, D., and Colson, W. B., "Multi-pass Transverse Mode Effects in Free Electron Laser," accepted by Nuclear Instruments and

Methods in Physics Research.

Hall, J., Wong, R.K., Blau, J., and Colson, W.B., "Simulations of the SLAC X Ray Free Electron Lasers," accepted by and SPIE OE/LASE '94 Gas, Metal Vapor, and Free Electron Laser and Applications Conference, Los Angeles, CA, 26 January 1994.

CONFERENCE PRESENTATIONS: Quick, D., Blau, J., Wong, R.K., and Colson, W. B., "Phase Space Simulations of Electrons Bunching and Power Output in the Novosibirsk/SELENE FEL," Fifteenth International Free Electron Laser Conference, The Hague, The Netherlands, August 1993.

Hall, J., Wong, R.K., Blau, J., and Colson, W.B., "Simulations of the SLAC X Ray Free Electron Laser," presented at the SPIE OE/LASE '94 Gas, Metal Vapor, and Free Electron Laser and Applications Conference, Los Angeles, CA, 26 January 1994.

THESES DIRECTED: Sturgess, K.A., "A Study of the Amplification of Laser and VLF Waves Using a Simple Pendulum Model," Ph.D. Dissertation in Physics 1993.

DOD KEY TECHNOLOGY: Propulsion and Energy Conversion.

KEYWORDS: Free Electron Lasers, Ship Defense, and High Energy Laser.

PHALANX GUN DISPERSION STUDY

W.B. Colson, Professor

Department of Physics

Sponsor and Funding: Naval Surface Warfare Center, Dahlgren

OBJECTIVE: The numerical analysis of the PHALANX Gun shows how mechanical oscillations can contribute to the dispersion.

SUMMARY: A numerical analysis of the modes of oscillation of the PHALANX Gun shows that the observed dispersion can be attributed to the flexing of the rotating six-barrel system in its breech. This research provides the first numerical finite-element model of the PHALANX Gun. The model includes the six-barrels with brackets, the breech, and bearings that hold the rotating six-barrel system. Measurements of the frequency spectrum of a single barrel show agreement with a numerical model of a single barrel. The complete model of the six-barrel system and breech is then driven by impulses corresponding to the firing of bullets 75 Hz on the top barrel of the six-barrel system. Damping is provided by two recoil adapters supporting the lower portion of the gun breech. Upon firing, the numerical model is observed to set back by about 1 cm due to recoil, in agreement with the actual gun, and

oscillations of the gun barrel tips are observed. The oscillations of the barrel tips are at about 15 Hz frequency with about 3 mm displacement. This is sufficient to explain the observed dispersion in a firing PHALANX Gun. This success of this modeling effort stimulated industry to develop a similar finite-element model to analyze the mechanical vibrations of the gun.

THESES DIRECTED: MacNeil, D.P., LT, USN, "Normal Modes of Oscillation of the VULCAN PHALANX Close-In Weapon System," Master's Thesis in Physics, 1993, Advisors: Colson, W.B., and Gordis, J. H.

Peterschmidt, J.C., LT, USN, "Normal Modes of Vibration of the PHALANX Guns," Master's Thesis in Physics.

DOD KEY TECHNOLOGY: Design Automation, Other.

KEYWORDS: PHALANX Gun, Ship Defense, and Finite-Element Model.

WAVELENGTH CONTROL OF FREE ELECTRON LASERS

W.B. Colson, Professor

Department of Physics

Sponsor and Funding: Stanford University High Physics Laboratory

OBJECTIVE: Research studies the control of the Free Electron Laser Wavelength by means of feedback on the electron beam energy.

SUMMARY: The Free Electron Laser FEL is continuously tunable over a wider range of wavelengths than any other laser of any kind. The FEL optical wavelength is inversely proportional to the square of the energy of the relativistic electron beam. The experimenters at the Stanford University High Energy Physics Laboratory use an FEL driven by short electron pulses from a superconducting linear accelerator for medical research. They use a feedback control system to modify the electron beam energy in order to stabilize the optical wavelength. We have developed simulations of the Stanford FEL, in order to better understand how the optical pulse changes its frequency and to establish the imitations of this method of wavelength control.

PUBLICATION: Pinkley, W.R., Wilkenson, W., Wong, R.K., Blau, J., and Colson, W.B., "Resonant Wavelength Modulation in a Free Electron Laser," accepted by Nuclear Instruments and Methods in Physics Research.

CONFERENCE PRESENTATION: Pinkley, W.R., Wilkenson, W., Wong, R.K., Blau, J., and Colson, W.B., "Resonant Wavelength Modulation in a Free Electron Laser," Fifteenth International Free Electron Laser Conference, The Hague, The Netherlands, August 1993.

THESIS DIRECTED: Wilkenson, W.F., LT, USN, "A Theory for Optical Wavelength Control in Free Electron Laser Oscillators," Master's Thesis in Physics, 1993.

KEY TECHNOLOGY AREA: Software, Electronic Devices, Other.

KEYWORDS: Free Electron Laser, Wavelength Control, and Computers.

POWER BEAMING TO SPACE SATELLITES
WITH FREE ELECTRON LASERS

W.B. Colson, Professor
Department of Physics

Sponsor and Funding: Naval Postgraduate School

OBJECTIVES: We evaluate the use of a Free Electron Laser to beam power to satellites and rockets in space.

SUMMARY: The Free Electron Laser FEL is proposed by NASA to beam optical power to satellites and rockets in space. The SELENE FEL is follows a design proposed by scientists in Novosibirsk, Russia. The SELENE FEL design calls for a high power single-pass radiator. We are collaborating with the SLAC researchers on the simulation of the X-ray FEL which also uses a single-pass radiator. We are simulating both of these FELs and offering modifications for better performance.

PUBLICATIONS: Quick, D.D., Blau, J., Wong, R.K., and Colson, W.B., "Phase space Simulations of the Novosibirsk/SELENE FEL," accepted by SPIE OE/LASE '94 Gas, Metal Vapor, and

Free Electron Laser and Applications Conference, Los Angeles, CA., 26 January 1994.

Wong, R.K., and Colson, W.B., "Transverse Mode Effects in Free Electron Laser Oscillators," accepted by SPIE OE/LASE '94 Gas, Metal Vapor, and Free Electron Laser and Applications Conference, Los Angeles, CA 26 January 1994.

CONFERENCE PRESENTATION: Colson, W. B., "The Amplification of Optical Electric and Magnetic Fields," Free Electron Laser Seminar, FORM Institute voor Plasmafysica, Rijnhuizen, The Netherlands, 17 August 1993.

DOD KEY TECHNOLOGY: Computers, Electronic Devices, Other.

KEYWORDS: Free Electron Laser, High Energy Laser, and Space Beam Beaming.

NACIT INFRARED SEARCH AND TARGET DESIGNATION RESEARCH

A.W. Cooper, Professor

W.J. Lentz, Research Associate

E.C. Crittenden, Jr., Distinguished Professor

E.A. Milne, Associate Professor

Department of Physics

Sponsor: Naval Sea Systems Command PEO-SSD

Funding: NAVSEA PEO-SSD and Naval Postgraduate School DFR

OBJECTIVE: To evaluate experimentally the applicability to InfraRed Search and Target Designation (IRSTD) Systems of passive ranging to horizon targets by application of simultaneous signature measurement in the Red Spike and Blue Spike spectral regions, and to evaluate laser radar as an adjunct to the IRSTD. This is a continuing multi-year project, supported by the Naval Surface Electro-Optics Project Office.

SUMMARY: The NPS IRST (modified Advanced Demonstration Model of the AN/SAR-8 IRSTD), has previously been modified for background analysis on a desktop computer. FY93 emphasis has been on evaluation of passive ranging low-flying targets using intensity ratio in narrow wavebands ("Red" and "Blue" Spikes) in the wings of the 4.3 μm CO₂ atmospheric absorption. Ratio vs range has been computed using new high resolution propagation codes (HITRANPC and PCLNTRAN3P), and ambiguities in optimization of filter bands have been identified. Initial experiments are planned with a stationary infrared source using the portable AMBER AE-4128 focal plane array camera. Filters have been specified and purchased for room temperature operation external to the camera. The Amber 128x128 pixel InSb focal plane array camera recently received has been modified with an external mounting for rapid filter changing. Initial experimental verification of range estimates will be made using this system whose 12 bit

dynamic range, variable frame rate and convenient size make it suitable for evaluation of technique. An eye-safe lidar based on a Nd:YAG frequency doubled laser at 532 nm wavelength with eighteen inch output beam expansion optics has been built for cloud and target ranging and atmospheric transmission analysis in conjunction with the IRST. Performance has been verified by ranging to ground fog at 3800m and to clouds at ranges up to 1400m at night. Photon counting will be investigated for increased range and Raman scattering to provide additional information.

THESES DIRECTED: Regush, M.M., MAJ, CAF, "Development of a LIDAR for Integration with the Naval Postgraduate School Infrared Search and Target Designation (NPS-IRSTD) System," Master's Thesis in Electrical Engineering, June 1993.

Dick, J.H., LT, USN, "Analysis of Two-Color Passive Infrared Ranging Utilizing the AMBER AE-4128 Infrared Camera System," Master's Thesis in Physics, December 1993.

OTHER: Lentz, W.J., Cooper, A.W., and Regush, M.M., "Improved Klett Lidar Inversion Techniques," accepted for presentation at the SPIE Conference Atmospheric Propagation and Remote Sensing III, Orlando, FL, 1994, and publication in SPIE Proceedings.

DOD KEY TECHNOLOGY: Sensors,
Environmental Effects, Electronic
Devices.

KEYWORDS: Atmospheric Optics,
Infrared Sensors, LIDAR.

INFRARED TECHNOLOGY SUPPORT TO THE AEGIS PROGRAM

A.W. Cooper, Professor
P.L. Walker, Research Physicist
W.J. Lentz, Research Associate
Department of Physics
R.J. Pieper, Associate Professor
Department of Electrical and Computer Engineering
Sponsor and Funding: Johns Hopkins University, Applied Physics
Laboratory

OBJECTIVE: To evaluate the performance improvement to be gained by incorporation ofIRST in the AEGIS combat system and to provide support to the AEGIS program office in the area of Cost and Operational Effectiveness Analysis.

SUMMARY: This program was initiated in Quarter 4 of FY93 and continued through Quarter 1 of FY94. Evaluations have been made of possible locations for one or moreIRST scanners on the AEGIS CG-47 and DDG-51 platforms. Elevation above sea level, maximum range to horizon, geometrically maximum detection range, and possible baselines for triangulation were estimated for these sensor locations on these two platforms. A preliminary analysis of single baseline and double baseline triangulation methods of passive range estimation has also been carried out and will be applied to the sensor locations identified. In support of this program measurements of polarization contrast improvement in infrared imaging were made in the MAPTIP NATO measurement exercise held off the coast of the Netherlands in October and November 1993. Over 3500 images in horizontal and vertical polarized pairs were

obtained in the 3-5 and 8-12 μm wavebands using the dual band AGA-780 Thermal Imager with polarization analyzer. These will be analyzed during the coming year. Preliminary examination shows clear target-background contrast improvement by polarization filtering, particularly in the LWIR band. This is attributed to significant emission polarization of thermal radiation from the sea surface at near grazing angles.

THESIS DIRECTED: Chan, P.M., "Experimental Investigation of Infrared Polarization Effects in Target and Background Discrimination," Master's Thesis in Electrical Engineering, December 1993.

OTHER: Cooper, A.W., Lentz, W.J. and Chan, P.M., "Infrared Polarization Measurements of Ship Signatures and Background Contrast," accepted for presentation at SPIE Conference on Characterization, Propagation and Simulation of Sources and Backgrounds IV, Orlando 1994, and publication in SPIE Proceedings.

Technotes delivered to JHU/APL; to appear as NPS Technical Reports:

Pieper, R.J. and Cooper, A.W., "A Triangulation Method for Passive Ranging," Technote NACIT-94-1, November 1993.

Dick, J.H. and Cooper, A.W., "Passive Infrared Sensor Integration in CG-47 and DDG-51 Class Ships for Low Flier Defense," Technote NACIT-94-2, November 1993.

Cooper, A.W., Chan, P.M., and Lentz, W.J., "NPS Participation in MAPTIP Experiment," Technote NACIT-94-3, November 1993.

DOD KEY TECHNOLOGY: Sensors, Environmental Effects, Electronic Devices.

KEYWORDS: Atmospheric Optics, Infrared Sensors, IRST.

STRIKE WARFARE SUPPORT

A.W. Cooper, Professor

E.A. Milne, Associate Professor

W.J. Lentz, Research Associate

P.L. Walker, Research Physicist

Department of Physics

R.J. Pieper, Associate Professor

Department of Electrical and Computer Engineering

**Sponsor and Funding: Naval Research Laboratory, Monterey
Detachment**

OBJECTIVE: To provide experimentation support to the measurement and prediction of FLIR detection ranges for validation and improvement of the current Electro-Optical Tactical Decision Aid (EOTDA) code for operational FLIR performance prediction.

SUMMARY: This is a continuation of a program carried out cooperatively with NRL Monterey to evaluate FLIR Tactical Decision Aid codes by comparison of code predictions of detection range with observations from operational naval aircraft, using the R/V POINT SUR as an instrumented target. This measurement period was devoted to the EOTDA recently adapted for naval use. Measurements were performed in conjunction with the VOCAR meteorological cruise of the POINT SUR to Southern California in the period 23 to 31 August 1993. A set of fourteen thermistors was installed to sample the skin temperature of the POINT SUR for the duration of the cruise. Overflights by FLIR-carrying aircraft were coordinated by NRL. Meteorological data gathered by NPS

Environmental Physics Group will be coordinated with the skin temperature data for evaluation of EOTDA predictions. Polarization-filtered radiometric images of the R/V POINT SUR were taken using an shore-based 3-5 μm AGA Thermovision system from shore in Monterey Bay during the initial cruise day. The vertically and horizontally polarized pairs of images will be analyzed for degree of polarization in ship signature features and sea background, to evaluate target discrimination improvement by polarization filtering.

OTHER: Pieper, R.J. and Cooper, A.W., "A Visibility Model for MRTD Prediction," accepted for presentation at the SPIE Conference on Infrared Systems Analysis and Testing V, Orlando, 1994, and publication in SPIE Proceedings.

DOD KEY TECHNOLOGY AREA: Sensors, Electronic Devices, Environmental Effects.

KEYWORDS: Tactical Decision Aids, FLIR Performance.

FLIR PERFORMANCE PREDICTION CODE VALIDATION SUPPORT

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E.C. Crittenden, Jr., Distinguished Professor

E.A. Milne, Associate Professor

P.L. Walker, Research Physicist

W.J. Lentz, Research Associate

Department of Physics

**Sponsor and Funding: Naval Command Control and Ocean Surveillance
Center, R&D Division, (NRaD)**

OBJECTIVE: To evaluate and improve the accuracy of modeling of ship infrared signature and atmospheric path modification of target contrast for inclusion in Tactical Decision Aid codes for FLIR range performance, by comparison of model prediction with measurements made during the PREOS92 cruise of the R/V POINT SUR. This is a cooperative program with NRaD.

SUMMARY: This project constitutes the analysis phase of the PREOS92 experiment, organized by NACIT at NPS in conjunction with NRaD, utilizing the R/V POINT SUR as an instrumented target for FLIR range measurements. The NPS analysis in FY93 has been concentrated on the comparison of concurrent ship signature temperature values obtained remotely with air and land based radiometric infrared imagers and locally with an array of thermistors and a hand-held radiometer. A Piper Navajo aircraft operated by NRaD carried an AGA-780 Thermovision infrared imager and atmospheric profiling equipment. During the first day of the experiment concurrent radiometric thermal images were recorded at comparable ranges with the NRaD AGA and the similar NPS shore-based AGA system. Comparison pairs of shore-based and air-borne image files of similar aspect, time and range have been analyzed. The average Target Background Temperature Difference (TBSD) has been computed from the

radiometric images compensated for atmospheric path using modified LOWTRAN transmittance and path radiance. TBSD differences in the range of 0.5 degrees have been found between air and land based measurement. For more detailed evaluation of the atmospheric compensation algorithm, ship skin transistor temperature values have been compared with radiometric values read from image pixels selected to match the transistor locations, compensated for path. Variability in computed radiometric temperature is attributed to subjectivity of selection of pixel corresponding to transistor location. Comparison of hand-held radiometer with transistor temperatures shows very close agreement.

THESIS DIRECTED: Kreits, J.C., LT, USN, "Preliminary Evaluation of the PREOS Program for Determining Detection Ranges of Airborne FLIR Systems," Master's Thesis, December 1992.

OTHER: Comprehensive report to be published in FY94 .

DOD KEY TECHNOLOGY AREA: Sensors, Environmental Effects, Electronic Devices.

KEYWORDS: Atmospheric Optics, Infrared Sensors, FLIR Performance Models.

RESEARCH IN MULTIPLEXED INFRARED IMAGING
AND MULTISPECTRAL IMAGING

D.S. Davis, Associate Professor
Department of Physics

Sponsor and Funding: Naval Sea Systems Command

OBJECTIVE: The objectives of this research are to develop and to evaluate the performance characteristics of a new generation of fully multiplexed imaging and multispectral imaging devices.

SUMMARY: The new generation of devices will work at long (far infrared - millimeter) wavelengths, where efficient focal plane array detector technology is either not available or cannot be developed for practical reasons. The new instruments are based upon a novel scheme in which multiplexing is achieved by means of optically generated Kronecker products, rather than by traditional (Hadamard, cyclic redundancy, etc.) mask encoding approaches. This scheme is inherently less complex than traditional approaches, and it requires only a pair of discrete (as opposed to focal plan array) detectors for its implementation.

PUBLICATION: Davis, D.S., "Multiplexed Imaging by Means of Optically-generated Kronecker Products: 1. The Basic Concept," Applied Optics, Vol. 33, 1994, in press.

PATENT: Davis, D.S., "An Efficient and Versatile Method and Apparatus for Multiplexed Imaging Using Optically Generated Kronecker Products," Navy Case No. 74667; PTO Serial No. 07/973099 (pending).

DOD KEY TECHNOLOGY AREA: Sensors.

KEYWORDS: Passive, Infrared, Thermal Imager, Infrared Search & Track, Multiplexed Imaging, Multispectral Imaging.

STUDY OF ATMOSPHERIC TURBULENCE RELATED EFFECTS
FOR A STELLAR INTERFEROMETER

D.L. Fried, Research Professor
Department of Physics

Sponsor and Funding: Naval Research Laboratory

OBJECTIVE: Develop understanding of the way shot noise and turbulence effects interact to limit the ability of the interferometer's path-length inequality sensor to properly control the path-length adjustment.

SUMMARY: Work was conducted using two distinct approaches. The first approach was based on a fully analytic treatment and studied only the basic signal processing algorithm being planned for use by the developers of the NRL Big Optical Array. The second approach utilized computer simulation and allowed evaluation of alternative signal processing algorithms. As a consequence of the completion of the first approach we were able to establish an understanding of how the duration of the measurement period should be selected for the coherent integration portion of the signal processing, and the extent to which incoherent averaging of coherent results should be used, i.e. how many coherent integration periods should be combined in the incoherent summing part of the algorithm. We determined that for nominal observation conditions the limiting stellar magnitude at which the path-length inequality could be satisfactorily determined was $m_v = 11.25$.

The second approach has been implemented for the algorithm currently planned for use with Big Optical Array. The results of that simulation were found to be in good agreement with the $m_v = 11.25$ stellar magnitude result developed analytically. Several alternative signal processing algorithms have been formulated and evaluated. To date none has provided significantly better performance than the original algorithm.

CONFERENCE PRESENTATIONS: Fried, D.L., "Atmospheric Turbulence Optical Effects: Understanding the Adaptive-Optics Implications," presented at the NATO meeting on Adaptive Optics, Cargese, Corsica (France), June 1993.

Fried, D.L., "Interferometer Path-Length Inequality Determination: Expected RMS Error with a Faint Source," presented at the ICO conference on Active and Adaptive Optics, Garching, Germany, August 1993.

DOD KEY TECHNOLOGY: Sensors.

KEYWORDS: Turbulence, Stellar Interferometer, Noise Theory, Wavefront Distortion.

ELECTRO-OPTIC WIDE AREA SURVEILLANCE SYSTEM TECHNOLOGY

D.L. Fried, Research Professor

Department of Physics

Sponsor and Funding: Dr. Donald Hanson, United States

Air Force Rome Laboratory

OBJECTIVE: Formulated infrared sensor concepts and conduct the necessary analysis to establish that the sensor has adequate sensitivity to support an AWACS aircraft in the detection and tracking of theater ballistic missiles in boost phase.

SUMMARY: Several sensor concepts were formulated, all based on a scanning mode of providing coverage. Each was analyzed, taking account of atmospheric background effects, which it was found constituted the performance limiting phenomena. All of the concepts were adjusted as appropriate to insure adequate sensitivity. No fundamental problems were uncovered at the phenomenology level other than due to curvature of the earth and the

presence of high altitude clouds along the line of sight. Detector number and inherent sensitivity requirements and required aperture size were found to be relatively modest---well within the state of the art.

CONFERENCE PRESENTATION: Fried, D.L., "Vanity, Vanity --- Or Who Gets Credit for the Early Development of the Artificial Guide-Star Concept," presented at the meeting of the New England Chapter of the Optical Society of America, 23 September 1993.

DOD KEY TECHNOLOGY: Sensors.

KEYWORDS: Clutter, Filter Algorithm, Optimum Filter.

THERMOACOUSTIC LIFE SCIENCES REFRIGERATOR (TALSR)

S.L. Garrett, Professor

Department of Physics and Space Systems Engineering

Sponsor and Funding: NASA-Life Sciences Division and General Electric Government Services

OBJECTIVE: To design, fabricate, and space-qualify, a thermoacoustic refrigerator which would be suitable for storage of biological samples on the Space Shuttle.

SUMMARY: The ThermoAcoustic Life Sciences Refrigerator (TALSR) is designed to be a complete refrigeration system which can be used on-board the Space Shuttle to provide cooling for biological samples. It is required to provide 700 Btu/hr of cooling at 4°C in the "refrigerator mode" and 400 Btu/hr of cooling at -22°C in the "freezer mode" within an insulated enclosure with a volume of approximately 2 cubic feet. Due to the similarity of TALSR to a home refrigerator/freezer, it is being developed for NASA under a Cooperative Research and Development Agreement with General Electric Government Services.

PUBLICATIONS: Garrett, S.L., Adeff, J.A., and Hofler, T.J., "ThermoAcoustic Refrigeration for Space Applications," Journal Thermophysics and Heat Transfer (AIAA), Vol. 7, No. 4, 1993.

Garrett, S.L., Perkins, D.K., and Gopinath, A., "ThermoAcoustic Refrigerator Heat Exchangers: Design, Analysis, and Fabrication," accepted for publication in the Proceedings of the 10th International Heat Transfer Conference.

CONFERENCE PRESENTATIONS: Garrett, S.L., Hofler, T.J., and Perkins, D.K.

"ThermoAcoustic Refrigeration," Alternative Fluorocarbons Environmental Acceptability Study, Refrigeration and Air Conditioning Workshop, Oak Ridge National Laboratory, Breckenridge, CO, 23-35 June 1993.

Garrett, S.L. and Hofler, T.J., "ThermoAcoustic Refrigeration: from Space Shuttle to Market," Ozone-Safe Cooling Conference, Greenpeace, Washington, D.C., 18 October 1993.

Gaitan, D.F. and Garrett, S.L., "Dynamics of a Dual-Driver Acoustic Resonator and Control System Used for Refrigeration," Journal of the Acoustical Society of America, Vol. 94, No. 3, Pt. 2, p. 1773, 1993.

Perkins, D.K., Gaitan, D. Felipe, Russell, R., Gopinath, A., Morris, L.T., Mayfield, J.A., and Garrett, S. L., "Thermodynamic Performance of a High Power ThermoAcoustic Refrigerator," Journal of the Acoustical Society of America, Vol. 94, No. 3, Pt. 2, p. 1772, 1993.

Garrett, S.L., Gaitan, D.F., Perkins, D.K., and Helseth, D.A., "ThermoAcoustic Life Sciences Refrigerator," Journal of the Acoustical Society of America, Vol. 93, No. 4, Pt. 2, p. 2364, 1993.

DOD KEY TECHNOLOGY AREA: Environmental Effects.

KEYWORDS: Thermoacoustic, Heat Exchange, and Thermal Control Systems.

IMPROVED EFFICIENCY AND POWER DENSITY FOR THERMOACOUSTIC COOLERS

T.J. Hofler, Research Assistant Professor

Department of Physics

Sponsor and Funding: Office of Naval Research

OBJECTIVE: To perform basic research on thermoacoustic cooling for applications requiring high cooling power and a small temperature span. Such applications would include environmentally sound cooling onboard Navy ships.

SUMMARY: The following research was performed from 1 September 1993 (the onset of funding) to 31 December 1993. In order to increase the cooling power density of thermoacoustic coolers, the acoustic amplitude must be increased substantially. Increasing the cooling power density by nearly two orders of magnitude is conceivable.

However, the conventional understanding [Swift, JASA, 1986] is that the length of the heat exchangers must be approximately twice the peak acoustic particle displacement amplitude. High amplitude thermoacoustic engines would force the heat exchangers to be an extremely large source of acoustic dissipation and the resulting engine efficiency would be low.

It was felt that these conventional heat exchangers were unnecessarily inefficient, and with proper design, could be made much shorter and much more efficient. Rough calculations supported this hypothesis, and an experimental test-bed was designed and built. The test-bed is a heat driven prime mover (an acoustic motor) rather than a cooler, since large acoustic amplitudes are easy to achieve.

The results suggest that heat exchangers can be thermally effective at lengths that are a factor of 10 shorter than those suggested by Swift. A very large increase in high power thermoacoustic cooler efficiency should be possible.

CONFERENCE PRESENTATIONS: Hofler, T.J., "Effective Heat Transfer Between a Thermoacoustic Heat Exchanger and Stack," Journal of the Acoustical Society of America, Vol. 94, No. 3, Pt. 2, p. 1772, , Denver, CO, September 1993.

Castro, N., Hofler, T.J., and Atchley, A. A., "Experimental Heat Exchanger Performance in a Thermoacoustic Prime Mover," Journal of the Acoustical Society of America, Vol. 94, No. 3, Pt. 2, p. 1772, Denver, CO, September 1993.

Garrett, S. L., Perkins, D.K., Gaitan, F.D., and Hofler, T.J., "Thermoacoustic Cooling," Refrigeration and Air Conditioning Technology Workshop, Breckenridge, CO, June 1993.

THESIS DIRECTED: Castro, N.C., LT, USN, "Experimental Heat Exchanger Performance in a Thermoacoustic Prime Mover," Master's Thesis in Physics, December 1993.

DOD KEY TECHNOLOGY: Propulsion and Energy Conversion.

KEYWORDS: Thermoacoustic, Refrigeration, and Cooler.

THERMOACOUSTIC REFRIGERATOR DESIGNS FOR SPACE

T.J. Hofler, Research Assistant Professor

Department of Physics

Sponsor and Funding: Naval Research Laboratory

OBJECTIVE: The objective is to construct third generation prototypes of thermoacoustic refrigerators (TARIII) suitable for use in spacecraft, for the purpose of cooling electronics and sensors to cryogenic temperatures. The goal of this ongoing research is to improve the refrigerator performance and design on both a fundamental level and on a practical level.

SUMMARY: Over the last calendar year the following work was accomplished. Construction of the first experimental TARIII cooler was finished and it was tested. Although the numerical design model indicated that a cold temperature of 125° K should be achieved, the coldest measured temperature was 220° K. Our extensive instrumentation enabled us to understand the reason for the poor performance, and has given us a much better understanding of the limitations of the current linear thermoacoustic theory.

The second TARIII cryocooler design has been extensively modeled numerically and hopefully will side-step the problems associated with the first design. The model indicates a coefficient-of-performance, COP, in excess of 10% of Carnot at 150° K with colder temperatures possible. The prototype of this design was mostly constructed.

A great deal of time was spent developing two new electrodynamic acoustic

driver designs. The first and simpler of the two designs should provide modest amounts of power at a modest efficiency, and will be usable over a broad range of frequencies. The construction of one of these drivers is very nearly finished.

A second and more complicated driver design has also been partially developed, which should deliver high acoustic power and high efficiency in a compact unit, over a narrow frequency range.

PUBLICATION: Garrett, S.L., Adeff, J.A., and Hofler, T.J. "Thermoacoustic Refrigerator for Space Applications," Journal of Thermophysics and Heat Transfer, Vol. 7, No. 4, October - December 1993.

CONFERENCE PRESENTATION: Hofler, T.J. and Adeff, J.A. "Performance of a Thermoacoustic Refrigerator with an Improved Stack Geometry," Journal of Acoustical Society of America, Vol. 94, No. 3, Pt. 2, Denver, CO, September 1993.

OTHER: Patent submission in progress, "Improved Acoustic Drivers for Cooling Engines."

DOD KEY TECHNOLOGY: Propulsion and Energy Conversion, Electronic Devices, Sensors.

KEYWORDS: Thermoacoustic, Refrigeration, and Cryocooler.

THERMOACOUSTIC PIN STACKS

R.M. Keolian, Assistant Professor

Department of Physics

Sponsor and Funding: Office of Naval Research, Physics Division

OBJECTIVE: The primary objective of this research is to construct and test "pin stacks." It is hoped that this new stack geometry will improve the efficiency of thermoacoustically based refrigerators, heat pumps and prime movers. Secondary objectives include the exploration of the desirability and practicality of fractal heat exchanger designs and of parametric sound sources.

SUMMARY: Funding for this project started in the last few weeks of this reporting period, and little happened during that time. However, earlier this year a manuscript describing the idea was published and a patent disclosure was submitted, which are included below. A stack is the heart of a thermoacoustic engine, where the bidirectional conversion of energy from acoustic to thermal forms occurs. A conventional stack consists of a rolled mylar sheet. A pin stack improves this geometry by using an array of parallel fibers or "pins." This increases the ratio of "good" volume, where the thermoacoustic action is taking place, to the "bad" volume, where viscous losses are taking place. It has been calculated that pin stacks should improve the efficiency of energy conversion by 10

to 20%, and experimental work attempting to construct a pin stack has just begun. In our first version, we will try to run thousands of parallel wires between two copper heat exchangers.

PUBLICATIONS: Swift, G.W. and Keolian, R.M., "Thermoacoustics in Pin-Array Stacks," Journal of the Acoustical Society of America, Vol. 94, No. 2, Pt. 1, pp. 941-943, 1993.

PATENT: Keolian, R.M. and Swift, G.W., "Thermoacoustic Pin Stack," Navy Case No. NC75596, 1993.

DOD KEY TECHNOLOGY AREA: Propulsion and Energy Conversion, Sensors.

KEYWORDS: Thermoacoustics, Refrigeration, Acoustic Source, Heat Pump.

WAVE TURBULENCE AND SOLITON DYNAMICS

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A. Larraza, Research Assistant Professor

Department of Physics

Sponsor and Funding: Office of Naval Research, Physics Division

OBJECTIVE: This continuing project deals with experimental and theoretical studies of nonlinear random surface wave driven far off equilibrium. Investigations of the self focusing mechanisms of localized nonlinear structures are also considered.

SUMMARY: Theoretical investigations of nonlinearly interacting random waves driven far off equilibrium have led to the prediction of new propagating collective modes. In the frequency regime where the mean free path of interaction of waves is large compared to the wavelength of the mode, a theory analogous to the theory of Fermi liquids, where the role of quasiparticles is played by the surface waves, predicts the existence of a longitudinal and a transverse mode. An experiment is being conducted in a large wave tank with fans to create a wind driven background sea state. A computer controlled mechanical paddle modulates the background sea state, with the modulation length smaller than the mean free path. Preliminary results seem to indicate the first observation of the longitudinal collective mode as a nondispersive decrease in the background spectral energy density. The propagation speed was determined to be a function of the spectral peak frequency, in qualitative agreement with the theory.

PUBLICATIONS: Larraza, A. and Falkovich, G., "Collective Modes in Open Systems of Nonlinear Random Waves," Physical Review B, Vol. 48, pp. 9855-9857, 1993.

Larraza, A. "Physical Applications of Wave Turbulence: Wind Waves and Classical Collective Modes," in Nonlinear Waves and Weak Turbulence, Chap. 5, N. Fitzmaurice et al., ed., Birkhauser, Boston, MA, 1993.

COLLOQUIUM PRESENTATIONS: Larraza, A., "Wave Turbulence and Collective Modes in Open Systems of Nonlinear Random Waves," Applied Mathematics Program, University of Colorado at Boulder, 14 January 1993.

Larraza, A., "The Boltzmann Equation: From Particle Kinetics to Nonlinear Random Waves," Applied Mathematics Program, University of Colorado at Boulder, 15 January 1993.

CONFERENCE PRESENTATIONS: Keolian, R. and Larraza, A., "Collective Modes in Nonlinear Random Gravity Waves," ONR Nonlinear Ocean Waves Workshop, Washington, D. C., October 1992.

Lawrence, R.T., Yarber, R.K., and Keolian, R.M., "Search for Second Sound in Deep Water Gravity Waves," Journal of the Acoustical Society of America, Vol. 92, Pt. 2, pp. 2454, 1992.

THESES DIRECTED: Yarber, R.K., "Development and Calibration of Two and Four Wire Water Surface Wave Height Measurement Systems," Master's Thesis, December 1992.

Lawrence, R.T., LT, USN, "Experimental Inquiries into Collective Sea State Modes in Deep Water Surface Gravity Waves," Master's Thesis, December 1992.

DOD KEY TECHNOLOGY: Environmental
Effects.

KEYWORDS: Nonlinear Waves, Random
Waves, Ocean Waves.

INDUCTIVE COUPLING

X.K. Maruyama, Professor

Department of Physics

Sponsor and Funding: Naval Air Warfare Center

OBJECTIVE: Aircraft electromagnetic pulse and lightning hardening programs have incorporated direct-drive technology to simulate EMP/lightning electromagnetic effects. The effort proposed here is to empirically test and characterize several inductive couplers used in the EMP/EMI test program at the Naval Air Warfare Center, Patuxent River, MD.

In this program, we will: (1) Investigate the transfer characteristics of inductive couplers used in the Patuxent River Aircraft Test Center; (2) These inductive coupler will be provided by the Naval Air Warfare Center; and (3) A Final report containing findings and recommendations for application in the aircraft test

program will be prepared as a Naval Postgraduate School Master of Physics thesis.

SUMMARY: The objectives one through three above have been accomplished. A final report containing findings and recommendation for choosing among the inductive couplers provided has been issued.

THESIS DIRECTED: Miller, Guy A., "Coupler Technology Evaluation for Lightning Direct Drive Tests at NAWC, Patuxent River, Maryland," Master's Thesis in Physics, June 1993.

DOD KEY TECHNOLOGY: Other

KEYWORDS: Aircraft EMP, Lightning, EMP/EMI, Coupler Technology, Simulation.

**FACILITIES SUPPORT FOR THE NAVAL
POSTGRADUATE SCHOOL LINAC AND FLASH X-RAY MACHINE**

**X.K. Maruyama, Professor
Department of Physics**

Sponsor: Naval Surface Warfare Center

Funding: Naval Postgraduate School

OBJECTIVE: The radiation sources at NPS, the 100 MeV RF electron linear accelerator and the 1.7 MV pulsed flash x-ray machine are required for a number of projects at NPS, including the study of unipolar arcing plasma physics, investigation of novel sources of coherent radiation and radiation effects in materials and electronic devices. These radiation sources are maintained by the Physics department, but are available to a variety of investigators from the Naval Postgraduate School and their associated external collaborators. These radiation source facilities are also used for classroom course instruction.

SUMMARY: In its twenty-eight year the electron linear accelerator continues to be a productive instrument for forefront research. The investigation of mechanisms in the study of parametric x-radiation, PXPR, revealed that for thick targets higher order Bragg scattering from virtual photons can be observed. This work has gained international attention. Our linac was the first laboratory in the western world to study this phenomenon. This work has been of such interest that PXR measurements are being pursued at the Naval Research Laboratory, Saskatchewan Accelerator Laboratory and the Johannes Gutenberg University in Mainz. Several Japanese laboratories including Osaka University and Tohoku University have also begun investigations. The present emphasis is to explain the greater than expected PXR radiation intensity from mosaic graphite. Further discussion of PXR is presented under

the project entitled Novel Sources of Coherent and Quasicoherent Radiation. E143 is a large collaboration of nearly 150 nuclear and high energy physicists who are conducting an experiment at the Stanford Linear Accelerator Center, SLAC. This experiment is to answer some puzzling questions on the structure of the proton and addresses the "Spin Crisis." The present understanding of quantum chromodynamics does not fully explain the spin of the nucleon from the constituent quark spins. E143 is an electron scattering experiment of polarized electrons on polarized protons. The polarized target is solid ammonia which must be prepared by inducing radiation damage. The Naval Postgraduate School linac was used to irradiate and prepare solid ammonia and deuterated ammonia targets. One student is involved in the main E143 experiment at SLAC wherein 20 GeV electrons are used as the projectile. Our x-ray detection expertise which we obtained from our coherent x-radiation program is being used to determine the target properties of solid ammonia.

The Radiological Affairs Support Office (RASO) conducted their tri-annual safety inspection. Recent requirement changes in the Code of Federal Regulations have made personnel absorbed radiation limits a factor of five smaller for the general public than was previously allowed (500 mrem/yr to 100 mrem/yr). This has required us to momentarily cease thesis projects and considerably improve radiation protection measures. Lead shielding has been

rearranged after we were able to identify a major source of background radiation as a focussing lens. These focussing lenses had been shorted for some time and they have been fixed. Two borated polyethylene doors weighing 600 and 300 lbs respectively have been installed to shield the experimental hall. This has cut down neutron flux from general public access areas. We have requalified our accelerator for operations. Further improvements are being pursued. Additional shielding in the form of water will be installed above the experimental vault. That we have been able to meet the new very stringent requirements is a considerable accomplishment and allows us to keep the linac operational.

The flash x-ray (FXR) machine has been productive this past year in the study of explosive plasma formation on electrodes. This investigation revealed that the electron beam from a cathode of a high voltage diode occurs within time scales of nanoseconds and the mechanisms are due to unipolar arcing. Similar unipolar arcing mechanisms are evident in the anode as well. The timing of the x-ray production, cathode interaction and anode interaction have been measured and are within a nanosecond of each other.

The results of the use of the radiation sources are listed separately under the individual project summaries where appropriate. Those listed below are not specifically listed under current sponsored projects.

PUBLICATIONS: Retzlaff, G.A., Beck, D., Caplan, H.S., Hallin, E.C., Sapp, W.W., Skopik, D.M., Blomqvist, Dodson, G., Dow, K., Farkhondeh, M., Flanz, J., Kowalski, S., Sargent, C.P., Tieger, D., Turchenitz, W., Williamson, C.F., Maruyama, X.K.,

Dodge, W., Lightbody, Jr., J.W., Ueng, T.S., Galoskie, R., McCarthy, J., Whitney, R.R., Dytman, B., Quinn, B., Von Reden, K., Schiavilla, R., and Tjon, J.A., "Threshold Electrodisintegration in the A=3 System."

Maruyama, X.K., Hellstern, M.J., Reid, C.B., Fiorito, R.B., and Rule, D.W., "Optical Transition Radiation Interferometry and Beam Emittance Measurements," Nuclear Instruments and Methods, Vol. B79, p. 788, 1993.

Fiorito, R.B., Rule, D.W., Maruyama, X.K., Peistrup, M.A., and Ho, A.H., "Observation of Higher Order Parametric X-ray Spectra in Mosaic Graphite and Single Silicon Crystals," Physical Review Letter, Vol. 71, p. 704, 1993.

Fiorito, R.B., Rule, D.W., Piestrup, M.A., Ho, A.H., Li, Q., and Maruyama, X.K., "Parametric X-ray Generation from Moderate Energy Electron," Nuclear Instruments and Methods, Vol. B79, p. 758, 1993.

CONFERENCE PRESENTATIONS: Maruyama, X.K., DiNova, K., Snyder, D., Li, Qiang,, Piestrup, M.A., Fiorito, R.B., and Rule, D.W., "A Compact Tunable X-ray Source Based on Parametric X-ray Generation by Moderate Energy Linacs," Particle Accelerator Conference, Washington, D.C., 17-20 May 1993.

Maruyama, X.K., Fasanello, T., Rule, D.W., Rietdyk, H., Piestrup, M.A., and Fiorito, R.B., "A Method for Measuring Dark Current Electron Beams in an RF Linac," Particle Accelerator Conference, Washington, D.C., 17-20 May 1993.

Fiorito, R. B., Rule, D.W., Maruyama, X.K., DiNova, K.L., Evertson, M.J., Piestrup, M.A., and Ho, A.H., "Higher Order Parametric X-ray Spectra in Mosaic and Single Crystals," Inter-

national Symposium on Radiation of Relativistic Electrons in Periodical Structures, REPS-93, Tomsk, Russia, 6-10 September 1993.

Maruyama, X.K., Fasanello, T., Rule, D.W., NiNova, K., Piestrup, M.A., and Fiorito, R.B., "A Method for Measuring Dark Current Electron Beams in an RF Linac and Its Application to Determine the Absolute Intensity of PXR Spectra," International Symposium on Radiation of Relativistic Electrons in Periodical Structures, REPS-93, Tomsk, Russia, 6-10 September 1993.

OTHER: Current external collaborators, institutions and topics include: Fiorito, R. and Rule, D., Naval Surface Warfare Center, optical transition radiation, parametric x-rays; Piestrup, M.A., et al., Adelphi Technology, x-ray transition radiation and x-ray optics, parametric x-rays; Johnson J., University of Wisconsin and the E143 collaboration at SLAC, polarized frozen ammonia targets and the nucleon spin crisis.

THESES DIRECTED: Willis, Gregory, "Investigation of Onset of Plasma Formation at Anode of Fast-Pulsed High-Voltage Diode," Master's Thesis in Physics, March 1993.

Callahan, Michael O., "X-ray Pulse Considerations and Electron Flow in High Voltage," Master's Thesis in Physics, December 1993.

Wright, Charles M., "Time Resolved Measurements of Light Produced by Onset of Plasma Formation on Electrodes of Fast Pulsed High Voltage Biodes," Master's Thesis in Physics, December 1993.

DOD KEY TECHNOLOGY: Electronic Devices.

KEYWORDS: Radiation Source, Linac, Accelerator, Parametric x-radiation, Transition Radiation, Quantum Chromodynamics, Flash x-ray machine, unipolar arcing.

SPACE POWER EXPERIMENT ABOARD ROCKET (SPEAR)

**R.C. Olsen, Associate Professor
Department of Physics
Sponsor and Funding: Defense Nuclear Agency**

OBJECTIVE: Support design phase for the SPEAR III project. In particular advise on the charging behavior experienced in SPEAR I, and on instrumentation to be flown in the new mission. Support chamber tests at NASA/LeRC Plum Brook facility. Analyze particle and wave data.

SUMMARY: Preliminary tests were conducted at the Plum Brook facility. Final tests were cancelled due to funding constraints. The rocket was successfully launched on 15 March 1993. Funding cutbacks eliminated

analysis funds, however, so subsequent work has been unsupported. James Morris, an NPS student, attended the Plum Brook tests in 1992, and the launch. Completion of thesis due in 1994.

THESIS DIRECTED: Morris, James, "Space Experiments Aboard Rockets: SPEAR III," due in March 1994.

DOD KEY TECHNOLOGY: Environmental Effects.

KEYWORDS: Spacecraft Charging.

LIQUID METAL ION GUN FLIGHT EXPERIMENT

**R.C. Olsen, Associate Professor
Department of Physics
Sponsor and Funding: NASA/GSFC**

OBJECTIVE: Prepare charge control experiment for launch on the European Space Agency (ESA) Cluster satellite mission. NPS responsibilities are to procure tile substrate, support charging analysis.

SUMMARY: This ongoing study continues. Delivery of the flight units by the principal investigator (Dr. Riedler, Graz, Austria) has begun. Attended team meeting in Oslo, Norway.

DOD KEY TECHNOLOGY: Environmental Effects.

KEYWORDS: Spacecraft Charging.

PLASMA MOTOR GENERATOR (PMG) - DELTA

R.C. Olsen - Associate Professor

Department of Physics

Sponsor and Funding: NASA/JSC

OBJECTIVE: Support design phase and launch for the PMG-Delta experiment. The experiment is an electrodynamic tether, designed to test plasma contactor technology.

SUMMARY: PMG-Delta was successfully launched in June 1993. Olsen supported the activity by working at the Hawaii ground radar site. Flight data were reduced at NPS. Student thesis work was initiated.

CONFERENCE PRESENTATION: Olsen, R.C., McCoy, J.E., Grossi, M.D., Carroll, J.A., Dobrowolny, M., and Jost, J., "High Current Electrodynamic Tether Investigations by the PMG Experiment," Fall Meeting of the American Geophysical Union, San Francisco, CA, 9 December 1993.

DOD KEY TECHNOLOGY: Environmental Effects.

KEYWORDS: Spacecraft Charging.

EQUATORIALLY TRAPPED PLASMAS

R. C. Olsen - Associate Professor

Department of Physics

Sponsor and Funding: Naval Postgraduate School

OBJECTIVE: Study the nature of equatorially trapped plasmas, and the interactions between such plasmas and the magnetosphere filling problem.

SUMMARY: Data from the AMPTE/CCE and Los Alamos 1989-046 satellite were analyzed. In this ongoing project, several surveys were conducted. The most intriguing element discovered to date is a link between the ionospheric photoelectron flows and the equatorially trapped electrons.

THESES DIRECTED: Lantto, Eric S., "Detailed Analysis Case Studies of Trapped Plasmas at the Earth's Magnetic Equator," Master's Thesis, June 1993.

Laszakovits, John S., "Ionospheric Photoelectrons Measured at Geosynchronous Orbit," Master's Thesis, June 1993.

DOD KEY TECHNOLOGY: Environmental Effects.

KEYWORDS: Space Plasmas.

THE PHYSICS OF HIGH VOLTAGE BREAKDOWN

F. Schwirzke, Professor

Department of Physics

Sponsor and Funding: Naval Postgraduate School

OBJECTIVE: To understand the high voltage breakdown process and the process of plasma formation on the surfaces of electrodes of a vacuum diode. This is a continuing project.

SUMMARY: Electrical breakdown and formation of cathode spots are basic processes in many areas of high voltage engineering and pulsed power technology. Micron-sized cathode spots form within nanoseconds on the cathode of a vacuum diode, vacuum, arc, and most other discharges. Despite the fundamental importance of cathode spots for the breakdown process, their structure and the source of the highly localized energy density were not well understood. A self-consistent physical model of the breakdown process has been developed. Field emission of electrons from spots on the cathode leads to desorption of neutral molecules. A positive space charge is formed by ionization of the desorbed neutrals which further enhances field emission. Surface heating of the electron emitting spot by ion bombardment is by orders of magnitude a more efficient energy deposition mechanism than the previously believed Joule heating. The localized buildup of plasma above the electron emitting spot leads to pressure and electric field distributions which ignite unipolar arcs. The high current density of the unipolar arc provides the "explosive" like formation of a cathode spot plasma. Experimental results obtained with the NPS Flash X-Ray and Electron Accelerator System confirm the new breakdown model.

PUBLICATIONS: Schwirzke, F., Hallal, M.P., Jr., and Maruyama, X.K., "Onset

of Breakdown and Formation of Cathode Spots," IEEE Transactions on Plasma Science, Vol. 21, No. 5, October 1993. (Invited Paper).

Schwirzke, F., Hallal, M.P., Jr., and Maruyama, X.K., "The Physics of Vacuum Breakdown," in Proceedings of the 9th International Conference on High Power Particle Beams, Washington, D.C., 25-29 May 1992, Vol. 2, National Information Service PB92-206168, 1993.

Schwirzke, F., "The Physics of Vacuum Breakdown," Conference Record, IEEE Catalog No. 93CH3334-0, 1993 IEEE International Conference on Plasma Science, Vancouver, BC, Canada, (Invited Paper), 7-9 June 1993.

Schwirzke, F., "The Physics of High Voltage Breakdown," in Proceedings of the XXI International Conference on Phenomena in Ionized Gases, Ruhr University Bochum, Germany, 19-24 September 1993.

Schwirzke, F., "The Physics of Vacuum Breakdown," Digest of Technical Papers, 9th International Pulsed Power Conference, Albuquerque, NM, 21-23 June 1993.

CONFERENCE PRESENTATIONS: Schwirzke, F. and Carter, J.P., "Magnetic Field Generation in Shockwaves," 1993 Annual Meeting of the Division of Plasma Physics of the American Physical Society, 1-5 November 1993, St. Louis, MO. Abstract published in Bulletin, American Physical Society, Vol. 38, p. 1904, 1993.

Schwirzke, F. and Carter, J.P., "Magnetic Field Generation in Shock-

waves," 11th International Conference on Laser Interaction and Related Plasma Phenomena, Monterey, CA, 25-29 October 1993.

THESES DIRECTED: Willis, Gregory, "Investigation of Onset of Plasma Formation at Anode of Fast Pulsed High-Voltage Vacuum Diode," Master's Thesis, March 1993.

Callahan, Michael O., "X-Ray Pulse Considerations and Electron Flow in High Voltage Diodes," Master's Thesis, December 1993.

Wright, Charles M., "Time Resolved Measurements of Light Produced by Onset of Plasma Formation on Electrodes of Fast Pulsed High Voltage

Diodes," Master's Thesis, December 1993.

OTHER: A paper "Magnetic Field Generation in Shockwaves," by Carter, J.P. and Schwirzke, F. has been submitted for publication in a book Laser Interaction and Related Plasma Phenomena, Vol. 11, H. Hora and G.H. Miley, eds.

DOD KEY TECHNOLOGY: Other.

KEYWORDS: High Voltage Breakdown, Cathode Spots, and Vacuum Diode.

THE BIRTHS OF JET DROPS FROM BUBBLES
BURSTING ON WATER SURFACES

D.E. Spiel, Research Associate Professor
Department of Physics

Sponsor and Funding: Office of Naval Research

OBJECTIVE: Derivation of the aerosol source function for ocean whitecaps.

SUMMARY: The droplets produced by bubbles bursting on the surface of the sea are important to air-sea exchanges. To understand this exchange requires a knowledge of the size and ejection speeds of both jet and film drops as a function of bubble size. Until recently there has been scant data on these important parameters. Development of new techniques, however, has allowed the simultaneous measurement of both droplet sizes and ejection speeds for all the jet drops produced by a collapsing bubble. In addition to the determination of droplet sizes and ejection speeds, the height above the surface and the time (measured from the first moment of burst) at which

the top drop separates from the ascending jet have been measured as a function of parent bubble size.

PUBLICATIONS: Spiel, D.E., "The Number and Size of the Jet Drops Produced By Air Bubbles Bursting on A Fresh Water Surface," Journal of Geophysical Research, Vol. 99, pp. 10289-10296, 1994.

Spiel, D.E., "The Sizes of the Jet Drops produced By Air Bubbles Bursting on Sea and Fresh Water Surfaces," Tellus, in press.

DOD KEY TECHNOLOGY AREA: Environmental Effects, Other.

KEYWORDS: Bubble, Jet drop, Whitecap.

A NEW METHODOLOGY FOR SUPPORTING C3I REQUIREMENTS

J. Sternberg, Professor

R. Thackeray, Adjunct Research Professor

Department of Physics

Sponsor and Funding: Director, Net Assessment, OSD

OBJECTIVE: The goal of this project is to develop and exercise a new methodology for assessing the contribution of non-organic sensor information on the effectiveness of a battle force which, for example, is suitable for use in justifying C3I requirements.

SUMMARY: A new three element methodology is being developed to achieve the program objective. The key element of the methodology is a unique wargame in which the non-organic information can be treated as the experimental variable affecting the tactical choices made by the commanders. The methodology has been adapted to contingency operations including strikes ashore and anti-air warfare in a littoral environment. The modifications to the game-support software package have been tested and perform to current speci-

fications. A full systems test, using officers with carrier battle group experience as players, is in the planning stage. Following any further modifications resulting from the test program, the methodology will be applied to a selected real-world problem.

OTHER: Progress during this period has been documented in a series of working papers and reports covering the development and results of the software testing program, the generation of manual AAW models to support the system tests, the rationale for the design of message flows in the simulation of the performance of the "TRAP" system, etc.

DOD KEY TECHNOLOGY AREA: Other.

KEYWORDS: C3I, Wargaming, and Requirements.

**ATMOSPHERIC CHARACTERIZATION FOR THE AIR FORCE AIRBORNE LASER
INSERTION PROGRAM**

**D.L. Walters, Associate Professor
Department of Physics**

**Sponsor and Funding: U.S. Air Force Phillips
Laboratory, Kirtland Air Force Base, NM**

OBJECTIVE: The Naval postgraduate School had the mission to develop high resolution probe sensors and perform measurements of strato-spheric turbulence.

SUMMARY: During FY 94, the US Air Force Phillips Laboratory and the Ballistic Missile Defense Office established the Airborne Laser Technology Insertion Program. Early analyses showed that atmospheric turbulence along near horizontal 100-500 km paths in the strato-spheric was a critical issue that had to be resolved in order to pursue an airborne laser option. In July 1992, the Phillips laboratory initiated a three pronged, aircraft, balloon, optical measurement program. NPS had the task of making measurements of the magnitude and spatial spectrum of turbulence in the stratospheric using balloon probes. During August-October NPS developed a few stratospheric probe sensor packages. A joint NPS balloon USAF KC-135 mission occurred over Monterey on 3 November 1992. On 13-14 December..... a joint NPS, Air Force Geophysics Laboratory companion calibration occurred with two different balloon systems. During 19-31 January 1993, NPS launched 6 research probe packages as a part of the key program mission the ABEL-X mission at Malmstrom, AFB, Montana, as two aircraft separated by 50-100 km collected laser scintillation data. During February and March 1993, NPS developed the technique of using two balloons to collect data on both the ascent and descent phases of a launch. A second, independent

Airborne Laser measurement program was the development and execution of acoustic sounder measurement for a laser propagation stratospheric simulation test in August - October 1992, at the USAF Starfire Optical Range, NM.

PUBLICATIONS: Krause-Polstorff, J., Murphy, E.A., and Walters, D.L., "Instrument Companion: Corrected Stellar Scintillometer versus Isoplanometer," Applied Optics, Vol 32, No. 21, pp. 4051-4057, July 1993.

Walters, D.L., "Measurements of Optical Turbulence, Using Higher Order Structure Functions," Applied Optics, July 1993.

CONFERENCE PRESENTATIONS: Walters, D.L., "NPS Balloon Measurement Status," briefing to BMD Office, Phillips Laboratory, 28 November 1992.

Walters, D.L. and Galarowitz, D. "Stratospheric Balloon Measurements," Airborne Laser Data Review with Industry, Kirtland Air Force Base, Vol. 2, April 1993.

THESES DIRECTED: Gast, V. J., LT, USN, "Characterization of Atmospheric Turbulence for High Resolution Imaging and Laser Propagation Objective," Master's Thesis, December 1992.

Roper, D. S., CPT, USAR, "Investigation of Systematic Effects in Atmospheric Microthermal Probe Data," Master's Thesis, December 1992.

Cherry, D. A., MAJ, USAR, "Calibration of a High Frequency Monostatic Acoustic Echosounder," Master's Thesis, June 1993.

O'Brien, M. P., LT, USN, "Development of Therosonde Methods for the Collection of High Resolution Optical Turbulence Profiles," Master's Thesis, June 1993.

DOD KEY TECHNOLOGY AREA: Sensors.

KEYWORDS: Stratospheric Turbulence and Balloon Sensors.

**DEVELOPMENT OF AUTOMATED METHODS FOR IN-SERVICE SONAR
TRANSDUCER PERFORMANCE MONITORING**

O.B. Wilson, Professor

S.R. Baker, Associate Professor

Department of Physics

Sponsor: Naval Sea Systems Command PM-390-TC4

OBJECTIVE: The objective of this research program is to develop and apply automated methods for the testing of submarine sonar transducers as installed in the submarine. This has been a continuing project.

SUMMARY: Procedures for measuring the electrical properties of transducers, developed at NPS, are part of a Complex Immittance Measurement (CIM) system. The CIM software for the DT-605 hydrophone was used in the laboratory to study the effects of ambient temperature on the electrical properties of this hydrophone. It is suspected that hydrophones subjected to extreme cold or hot temperatures could lead to adverse interpretation of the results of such measurements made at dock-side. Equivalent electrical circuit parameters for the DT-605 may be extracted from measurements of its input electrical impedance. Four DT-605 hydrophones were tested over a range of temperatures in air and the equivalent network parameters were determined using a nonlinear least-squares curve fitting procedure. The impedance magnitude at the nominal operating frequency and low frequency resistance were also measured. An approximate linear dependence of the parameters on temperature was observed for both the wide beam and narrow beam subarrays of the DT-605 hydrophone.

Software for conducting in-service testing of DT-574 and TR-317 sonar sensors, previously developed at NPS for use in the CIM System, was adapt

ed for use with a newly developed switchbox. Under computer control, this box switches connections between measuring instruments and the transducer elements in an array and permits the automated collection of data on the array element properties. This automated CIM test will be able to reduce the amount of time and manpower presently required by conventional methods while eliminating nearly all errors incurred from manual tabulations. A field test was conducted onboard an Ohio-class submarine and the modified software was verified. A new portable laptop PC running the CIM software under High-Tech (HT) Basic was used as the controller in these field-tests.

THESES DIRECTED: Robinson, Ronald B., LT, "An Investigation of the Effects of Temperature Changes on the Equivalent Network Parameters for the DT-605 Transducer," Master of Science in Applied Physics, March 1993, (Co-advisors: Baker, S.R. and Wilson, O.B.).

Guerra, Louis P., LT, "Adaptation of a Computer-Controlled, Multiple-Transducer Switch Box for the Complex Immittance Measurement (CIM) System to Test the DT-574 Hydrophones in the AN/BQQ-6 Sonar," Master of Science in Applied Science, September 1993, (Co-advisors: Baker, S.R. and Wilson, O.B.).

OTHER: Wilson, O.B. and Baker, S.R., "Sonar Transducer Performance Monitoring and Prediction, End of Year Report," NPS-PH-94-004PR, December 1993.

DOD KEY TECHNOLOGY AREA: Sensors.

KEYWORDS: Tranducer, Sonar, Hydro-
phone.

**DEPARTMENT
OF
PHYSICS**

**1993
Faculty Publications
and Presentations**

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Blau, J., Frost, D.J., and Colson, W.B., "Amplification of Short Optical Pulses in the Boeing APLE Amplifier," Nuclear Instruments and Methods in Physics Research, Vol. A331, p. 645, 1993.

Colson, W.B., Gately, B., Caudle, D.L., and Sturgess, K., "Analogies Between the Free Electron Laser and Whistler Mode Amplification in the Magnetosphere," Nuclear Instruments and Methods in Physics Research, Vol. A331, p. 522, 1993.

Denk, W., Keolian, R.M., Ogawa, S., and Jelinski, L.W., "Oscillatory Flow in the Cochlea Visualized by Novel Magnetic Resonance Imaging Technique," Proceedings in National Academy of Science USA, Vol. 90, pp. 1595-1598, 1993.

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Fiorito, R.B., Rule, D.W., Maruyama, X.K., DiNova, K.L., Evertson, S.J., Osborne, M.J., Snyder, D., Rietdyk, H., Piestrup, M.A., and Ho, A.H., "Observation of Higher Order Parametric X-Ray Spectra in Mosaic Graphite and Single Silicon Crystals," Physical Review Letters, Vol. 71, p. 704, 1993.

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Garrett, S.L., "Linearized Least-Squares Data Analysis," Journal of the Acoustical Society of America, Vol. 94, No. 3, Pt. 2, p. 1855, 1993.

Garrett, S.L., Adeff, J.A., and Hofler, T.J., "Thermoacoustic Refrigerator for Space Applications," Journal of Thermophysics and Heat Transfer, Vol. 7, No. 4, pp. 595-599, October-December 1993.

Larraza, A., Denardo, B., Atchley, A., and Doff, S., "Absorption of Sound by Noise in One Dimension," Journal of the Acoustical Society, Vol. 93, Pt. 2, 4pPA3, 1993.

Larraza, A. and Falkovich, G., "Collective Modes in Open Systems of Nonlinear Random Waves," Physics Review B, Vol. 48, pp. 9855-9857, 1993.

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Morgan, H.D., Seyoum, H.M., Fortna, J.E., Humm, D.C., Asfaw, A., and Cleary, D.D., "Total Photoabsorption Cross Section of Molecular Nitrogen Near 83.4nm," Journal Geophysical Research, Vol. 98, p. 7799, 1993.

Perkins, D.K., Gaitan, D.F., Russell, R., Gopinath, A., Morris, L.T., Mayfield, J.A., and Garrett, S.L., "Thermodynamic Performance of a High Power Thermoacoustic Refrigerator," Journal of the Acoustical Society of America, Vol. 94, No. 2, Pt. 2, p. 1772, 1993.

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Sturgess, K., Frost, D.J. and Colson, W.B., "Short Pulse Evolution in the Boeing APLE Oscillator," Nuclear Instruments and Methods in Physics Research, Vol. A331, p. 650, 1993.

Swift, G.W. and Keolian, R.M., "Thermoacoustics in Pin-Array Stacks," Journal of the Acoustical Society of America, Vol. 94, No. 2, Pt. 1, pp. 941-943, 1993.

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**DEPARTMENT
OF
SYSTEMS MANAGEMENT**



**David R. Whipple, Jr.
Chairman**

DEPARTMENT OF SYSTEMS MANAGEMENT

The Department of Systems Management is responsible for academic programs designed to educate officers and DoD civilians in a variety of functional management specialties. The diversity of the faculty's professional expertise and scholarship is reflected in the wide variety of research projects conducted in the department.

In addition to permanent faculty, the department's research efforts have been augmented by the participation of a number of adjunct professors. The research projects cover a broad range of defense-related management issues, ranging from basic scholarly research projects to applied research designed to assist policy makers and operational decision makers. For ease of exposition, the research projects are grouped into the following functional areas: acquisition and contracting; logistics and transportation; information and technology management; financial management; manpower, personnel, and training analysis; Organization, management and policy analysis.

ACQUISITION AND CONTRACTING

Professor D. Lam continued his research project to identify and examine various characteristics of the contracting profession through the development and use of the taxonomical approach. The research effort involves three studies: in the first a classification scheme was developed; in the second, specific homogeneous goods with specific sets of buyers were examined; and in the third, Professor Lam examined the practical applications and benefits that can be gained through use of the taxonomy. In a second research project, Professor Lam examined the use of the simulated negotiation method in preparation for contract negotiations.

Professor O.D. Moses continued his program of research on the performance of cost estimation/cost progress models. The goal of this year's effort was to assess the forecast accuracy and reliability of alternative cost prediction models.

LOGISTICS AND TRANSPORTATION

Professor A. McMasters continued a multi-year project sponsored by the Navy Supply System Command to develop a wholesale level inventory model to be used by the Navy to replenish inventories of repairable items. In this year's effort, he concentrated on determining the distribution of net inventory and the relationship between the mean and variance of the net inventory distribution as a function of the various important parameters used by the Navy in its management of such items. In a second continuing project funded by Naval Air Systems Command, Professor McMasters is developing models to predict the savings in life-cycle costs of proposed engineering changes intended to improve reliability, maintainability, and sustainability of turbine aircraft engines for Naval aircraft. The first phase of this multi-year project examined current lifecycle cost models. The second phase is to validate the actual costs and logistics effectiveness of the aircraft engine Component Improvement Program (CIP) by

looking at historical data. A third phase was added this past year to address the problem of justifying warranties on aircraft engines.

Professor David Brown was involved in a research effort to examine and compare two procedures for specifying safety stock, namely, unit stockout cost and probability-of-stockout. Professor Brown is also engaged in research to continue the development of detailed track inspection procedures designed to support maintenance management of U.S. Army railroad networks, and to effectively communicate these procedures to potential users.

The Army Strategic Logistics Agency is sponsoring an umbrella research project that funds three research efforts: (1) Professor Rick Rosenthal's project on capital budgeting for research and development; (2) Professors Boger and Liao's research to assess Depot maintenance Models; and (3) Professor Dolk's project on model integration of Depot Maintenance Computer Models.

INFORMATION TECHNOLOGY MANAGEMENT

The Office of Technical Integration & Interoperability, OSD sponsored a project led by Professors James Emery and Dani Zweig to examine the use of the programming language Ada for developing automated information systems (AIS) within DoD, giving consideration to alternative languages and approaches for application software development.

Professor Norman Schneidewind continued his highly visible research work of software reliability models. His current project is sponsored by the Naval Surface Warfare Center, and involves the development of a methodology for applying metrics across multiple projects. Professor Schneidewind was also involved on a continuing research program to improve the prediction accuracy of a previously published Local Area Network (LAN) performance model.

Professors William Haga and Kenneth Euske collaborated on a research project to improve the process improvement process. The project is funded by the Office of Director of Defense Information. The specific goal of this project is to develop the redesign Experts and Practices (REAP) database to support DoD functional managers in undertaking business process re-engineering.

In a project sponsored by the U.S. Space Command, Professors Magdi Kamel, Dan Dolk and Tung Bui developed a prototype decision support system (DSS) to measure the trade-off between military satellite communications capabilities and user requirements for those capabilities. This effort requires the integration of several DSS's and their associated databases into a user-friendly comprehensive system.

Professor Kishore Sengupta and Anthony Ciavarelli (of the Aviation Safety Office) continued research on a project to develop a multimedia-based intelligent tutoring system. The system is for training aviators in the acquisition and use of perceptual skills required in flying with night vision devices. The project has been funded by the Naval Air Systems Command.

Professor Ramesh continued a multi-year project sponsored by the Naval Surface Warfare Center to develop models and mechanisms for requirements traceability in large scale systems development. This year's effort involved in a study of the current practices in DoD and contracting organizations involved in developing large scale complex systems and the development of a model of an improved traceability scheme. In a related study on capturing and reasoning with design rationale in systems development, Professor Ramesh completed the development of the REMAP (Representation and maintenance of Process Knowledge) model. This model and supporting mechanisms have been incorporated in the U.S. Air Force Rome Laboratory's next generation CASE (Computer Aided Software Engineering) prototype.

Professors Dan Dolk, S. Liao, D. Boger, and M. Ackroyd worked on a research project to review and analyze the existing version of PMSDA's Depot Maintenance Resource Prediction Model (DMRPM). This research will use data related to combat vehicles to identify and validate the resource predictive algorithms, and to identify additional decision needs of current users and areas for refinement.

The U.S. Coast Guard is sponsoring two research projects led by Professor Hamant Bhargava. The objectives of the first project are to develop an overall software architecture, an algebraic modeling language and a data modeling language for an integrated modeling environment for use in the U.S. Coast Guard. The second project has two objectives: (1) to explore and examine systematic ways to address the problem of fleet mix planning in the U.S. Coast Guard, and (2) to design, implement, test and evaluate models for fleet mix planning in the Coast Guard.

FINANCIAL MANAGEMENT

The National Industrial Security Program sponsored Professor J.G. San Miguel to conduct a field research at a sample of defense contractors to gather information from industry executives on the nature of security costs incurred on federal security requirements, the components of security costs, the accounting treatment for security costs, and the reporting of security costs. Professor San Miguel is also involved in a research project to develop a new approach to profit variance analysis that incorporates new theories concerning cost definitions, aggregation, and competitive analysis. This project is sponsored by the Activity Based Management Task Force, American Institute of Certified Public Accountants.

Professor L. Jones is involved in three concurrent research efforts. The first is a continuing research project to assess the roles, participants and relationships in the Navy system for Ship Maintenance and Repair and to analyze methods for improving the efficiency and cost effectiveness of the system. Selected issues in programming and budgeting for ship maintenance and repair are also examined. The objective of the second research project is to assess the budget and the impact of budget reductions in the AIRPAC, PACFLT command, to assess management control system and accounting changes to respond to budget austerity including those related to the DMR process and to analyze U.S.-Japan national defense resource burden-sharing. The project is sponsored by COMNAVAIRPAC. The goal of the third research project, which is sponsored by the Comptroller, DoD, is to assess the impact of budget reductions in DoD including

those related to the DMR process and to conduct a survey of quality assessment in DoD Financial Management Education and Training Institutions.

Professor K. Euske is continuing a research project sponsored by Commander, Naval Supply Systems Command. The specific objectives of this research project are: (1) Analyze the current management control system supporting the RAMP project; (2) Recommend adjustments to that system such that the output of the system will provide information that accurately appraises the RAMP project; and (3) Ensure that the system provides valid and reliable information regarding the cost, effectiveness, and efficiency of the RAMP project.

MANPOWER, PERSONNEL, AND TRAINING ANALYSIS

Professor George Thomas has refined his nationwide measurements of local recruit markets to include measures of the latent civilian market eligible for high tech Navy occupations, sponsored by Navy Recruiting Command (NRC). His work in this area has become an industry standard, and is used to drive NRC recruiting models. Professor Thomas is also developing a longitudinal data base, for U.S. Army Reserve Personnel Command (ARPERCEN), to study life cycle participation in the Army active and Reserve forces.

Professors D. Boger and S. Liao are collaborating on a research project, sponsored by the Army's Program Management Systems Development Agency, to review and analyze the existing version of the Depot Maintenance Resource Prediction Model for possible refinement and enhancement.

The OSD (Net Assessment) is sponsoring Professor's Gregory Hildebrant research effort to investigate issues associated with the maintenance of U.S. military-technological superiority into the twenty-first century.

Professors W. Gates and K. Terasawa are involved in a project sponsored by the Bureau of Naval Personnel to help develop a cost-effective mix of drug demand reduction programs in DoD. The objective is to identify the characteristics of the at-risk population and design specific initiatives to efficiently address that population.

The Deputy Chief of Naval Operations (MPT) N1/BUPERS is the sponsor of a project that provided umbrella funding within which individual projects were proposed and carried out by individual researchers. Professor Mehay coordinated the overall project and facilitated interactions between individual faculty and N1/BUPERS. There are two specific sub-projects. The first involves an analysis of the determinants of the decision by enlisted personnel to voluntarily separate from the Navy in response to the VSI/SSB bonus programs, and an analysis of the net effect of the program on retention. The focus of the second sub-project is an analysis of the propensity for nontraditional occupations among women.

Professor Mark Eitelberg was involved in a number of research projects for the Office of the Secretary of Defense (OSD), including: the Commission on Family Status and Initial Term of Service (as navy representative on the technical panel and director of the study of policies and programs); a study that examined the history and current status of the All-Volunteer Force (commemorating its

twentieth anniversary); and a study of ethnic participation in the U.S. and foreign militaries (as Defense Department representative on The Technical Cooperation Program, an international consortium of defense scientists).

Professors F. Barrett and Gail Thomas are collaborating on a project to study the causes and effects of sexual harassment in the U.S. Navy.

Professors Keebon Kang and K.L. Teresawa are collaborating on a project sponsored by the U.S. Army Recruiting Command. The project has two objectives: (1) to develop a transparent and documentable cost per output methodology for the U.S. Army recruiting activities; and (2) to identify the areas for cost-savings with the future changes in recruiting environment.

Professors David Whipple and Reuben Harris are leading a multi-year project to develop, field test, and implement a comprehensive Navy-wide executive management development program that will prepare selected Navy health care managers for executive positions in Navy MTFs. The project is sponsored by the U.S. Navy, Bureau of Medicine and Surgery.

ORGANIZATION, MANAGEMENT AND POLICY ANALYSIS

Professors Susan Page Hovevar, Gail Fann-Thomas, and Frank Barrett are collaborating on a research project sponsored by the Naval Air Warfare Center, Aircraft Division to gather, summarize, and interpret employee-based data regarding the effectiveness of a significant restructuring that occurred in 1992. In addition the research team will continue the regular administration, analysis and interpretation of an employee Quality of Work Life Survey.

Professors C. Jones, N. Roberts, and K. Sengupta are investigating how individuals, groups, and organizations make decisions in military and DoD related contexts at both the strategic and operational levels and to make recommendations for improvement. The sponsoring organization is the Naval Oceans Systems Center, San Diego, CA.

A STUDY OF ISSUES RELATED TO SEXUAL HARASSMENT

F.J. Barrett, Assistant Professor

G.F. Thomas, Associate Professor

Department of Systems Management

Sponsor and Funding: Naval Postgraduate School

OBJECTIVE: The goal of this project was to study the causes and effects of sexual harassment in the US Navy.

SUMMARY: This is part of a continuing study about gender issues in the US Military. For this study, more than 100 men and women Navy and Marine officers were interviewed. In-depth, semi-structured interview protocols were designed to elicit general views as well as detailed accounts of the experiences of female and male officers. Each interview was 1-3 hours in length. Qualitative data analysis identified common recurring themes.

Themes included how men view women's increased integration in the Navy and Marines as well as women's response to their treatment in a hyper-masculine environment.

CONFERENCE PRESENTATIONS: Thomas, G.F. and Barrett, F.J., "The Construction of Gender in the United

States Navy," Association for Business Communication, Western Regional Meeting, San Francisco, CA, March 1993.

Barrett, F.J., "Construction of Masculinity," Conference on Social Construction, NH, June 1993.

Thomas, G.F. and Barrett, F.J., "The Construction of Femininity in a Hyper-Masculine Organization: The US Navy," Association for Business Communication, Annual Convention, Montreal, Canada, November, 1993.

THESIS DIRECTED: Ernst, R.W. and Gilbeau, R.J., LT, USN, "Gender Bias in the Navy," Master's Thesis, June 1993.

DOD KEY TECHNOLOGY AREA: Other.

KEYWORDS: Women in the Military, Sexual Harassment.

NEWCOMER SURPRISE: AN EXTENSION AND
EXPLORATION OF LOUIS' CONCEPTUALIZATION

J.R. Barrios-Choplin, Visiting Assistant Professor
Department of Systems Management
Sponsors and Funding: Naval Postgraduate School,
University of Texas, and the University of Arizona

OBJECTIVE: The purpose was to extend newcomer socialization research as it relates to organizational surprise.

SUMMARY: The study found: over half of newcomer's surprises were pleasant; over 10% occurred prior to reporting to their jobs; the main sources were managers and supervisors; the main topics were status and caring; the main effects were emotional; and a significant number

of surprises were totally unexpected, versus unmet expectations.

OTHER: Paper submitted to the 1994 Academy of Management National Conference.

DOD KEY TECHNOLOGY AREA: Other.

KEYWORDS: Newcomer Socialization, Unmet Expectations, Surprise.

INTEGRATED MODELING ENVIRONMENT FOR THE U.S. COAST GUARD

**H.K. Bhargava, Assistant Professor
Department of Systems Management
Sponsor and Funding: U.S. Coast Guard**

OBJECTIVE: The objectives of this project were to develop an overall software architecture, an algebraic modeling language and a data modeling language for an integrated modeling environment for use in the U.S. Coast Guard. Related topics included development of methods for model version management, model validation, and for representation of assumption in modeling languages.

SUMMARY: Modeling environments should, insofar as possible, support modeling activities throughout the modeling life cycle, assisting modelers in creating, validating, executing, manipulating, revising, and explaining models. Executable modeling languages have proved useful in creation and execution of mathematical models. This research extends modeling languages by adding features for model validation (via the use of dimensional analysis) and for representing, and reasoning with, assumptions underlying models. These features were implemented in a prototype modeling environment based on the embedded languages technique, using Mathematica as a modeling language and solver.

PUBLICATIONS: Bhargava, H.K. and Kimbrough, S.O., "Model Management: An Embedded Languages Approach," Decision Support Systems, Vol. 10, No. 3, pp. 277-300, 1993.

Bhargava, H.K., "Dimensional Analysis in Mathematical Modeling Systems: A Simple Numerical Method," ORSA Journal of Computing, Vol. 5, No. 1, pp. 33-39, 1993.

CONFERENCE PRESENTATIONS: Bhargava, H.K., Krishnan, R., and Muhanna, W., "On Interconnection Languages in Modeling Environments," ORSA/TIMS Joint National Meeting, Phoenix, AZ, November 1993.

Bhargava, H.K., Krishnan, R., and Muhanna, W., "A Type System for Integrated Modeling Environments," ORSA/TIMS Joint National Meeting, Phoenix, AZ, November 1993.

Bhargava, H.K. and Krishnan, R., "On the Representation of Assumptions in Modeling Languages," ORSA/TIMS Joint National Meeting, Chicago, IL, May 1993.

Bhargava, H.K., Krishnan, R., and Whinston, A.B., "On Integrating Modeling and Collaborative Technology," Fourth Conference on Organizational Computing, Collaboration and Communication, Austin, TX, March 1993.

DOD KEY TECHNOLOGY AREA: Software.

KEYWORDS: Modeling Languages, Dimensional Analysis, Version Management.

FLEET MIX PLANNING IN THE U.S. COAST GUARD

H.K. Bhargava, Assistant Professor

K. Kang, Associate Professor

Department of Systems Management

Sponsor and Funding: U.S. Coast Guard

OBJECTIVE: The objectives of this project were: (a) to explore and examine systematic ways to address the problem of fleet mix planning in the U.S. Coast Guard, and (b) to design, implement, test and evaluate models for fleet mix planning in the Coast Guard.

SUMMARY: Fleet mix planning involves determining the "optimal" configuration of a fleet, in terms of the type of assets within the fleet and the numbers of each type, that an organization must hold in order to optimize its defined objective satisfying the various environmental and organizational constraints. Literature on fleet planning in various sorts of organizations was examined. We developed and evaluated mathematical models for determining

the Coast Guard's fleet under several assumptions of mission needs, demand projections, and asset utilization.

CONFERENCE PRESENTATIONS: Bhargava, H.K. and Kang, K., "Models for Fleet Mix Planning in the U.S. Coast Guard," presented to the Coast Guard Headquarters Office of Acquisition, and the Coast Guard R & D Center, March 1993.

Bhargava, H.K., "Fleet Mix Planning in the U.S. Coast Guard," The Netherlands Organization for Applied Scientific Research (FEL-TNO), Den Haag, May 1993.

DOD KEY TECHNOLOGY AREA: Software.

KEYWORDS: Fleet Mix Planning.

AUTONOMOUS FORCES IN COMBAT SIMULATION SYSTEMS

H.K. Bhargava, Assistant Professor

Department of Systems Management

Sponsor and Funding: Naval Postgraduate School

OBJECTIVE: The objectives of this project to design and develop a particular intelligent autonomous force program for use in conjunction with the NPSNET combat simulation system, and to investigate the coordination, command and control of multiple autonomous forces.

SUMMARY: The NPSNET project at the Naval Postgraduate School has addressed the modeling of combat forces consisting mainly of tanks, trucks, helicopters and airplanes. Simulated battles are carried out between opposing groups of combat forces with assumptions about, and representations of, the overall scenario, battlefield, terrain, com-

munications, and other relevant factors. This research extends this system by adding autonomous forces, forces controlled and represented by computer programs which make the "battlefield decisions" for these forces.

THESIS DIRECTED: Jacobs, R.A. and Steiner, J.P., "Improvements to Autonomous Forces through the Use of Genetic Algorithms and Rule Base Enhancement," Master's Thesis, March 1993.

DOD KEY TECHNOLOGY AREA: Software.

KEYWORDS: Combat Simulation, Autonomous Agents.

DEPOT MAINTENANCE RESOURCE PREDICTION MODEL:
VALIDATION, REFINEMENT, AND ENHANCEMENT

D.C. Boger, Professor of Economics

D.R. Dolk, Professor

S.S. Liao, Professor of Accounting

M.H. Ackroyd, Associate Research Professor

Department of Systems Management

**Sponsor and Funding: Program Management Systems Development
Agency, Headquarters, Department of the Army**

OBJECTIVE: The goal of this project is to review and analyze the existing version of the Depot Maintenance Resource Prediction Model for possible refinement and enhancement. This project is continuing into the next fiscal year.

SUMMARY: The principal focus of this research project is on the data, quantitative methods, and algorithms of the model. The research is using data from combat vehicles and aircraft to identify, validate, and refine the predictive algorithms of the model. The research will identify additional decision needs of current Army users (ODCSLOG, ASA(FM), HQ AMC) and decision needs of other potential DoD users. The feasibility of use of operational availability

data within the model will be evaluated. Additionally, those parts of the model which can support optimization algorithms will be identified, and implicit constraints which the data structure places on optimization within the model will be assessed. Additional questions which might be answered by the model will be identified.

OTHER: A technical report is in progress and will be completed at the end of the project.

DOD KEY TECHNOLOGY AREAS: Computers, Software, Other.

KEYWORDS: Model, Depot Maintenance, Resource Requirements, Decision Support, Validation.

**THE INTERNAL DYNAMICS OF TWO INVENTORY-THEORETIC
FREIGHT SERVICE CHOICE MODELS**

**D.G. Brown, Visiting Assistant
Department of Systems Management
(Unfunded)**

OBJECTIVE: Within the inventory-theoretic transportation literature, unit stockout cost and probability-of-stockout are the most popular procedures for specifying safety stock. The goal of this project was to examine and compare these two procedures with respect to criteria primarily based on microeconomic problems such as carrier-choice and the problem of minimizing the sum of shipper inventory and carrier costs with respect transportation service quality.

SUMMARY: The internal dynamics of both procedures were examined and compared graphically, and with application examples based on inventory cost surfaces. The principal finding was that anomalies found associated with the probability-of-stockout procedure, and their implied impact on application solutions, severely limits the usefulness of that procedure. A second finding challenged the common assumption that safety stock always increases with shipper inventory cost. In addition to microeconomic problems such as

those presented above, the results have implications for other applications such as shipper-decision-support for carrier-choice. A third procedure using fill rate was also examined to a limited extent.

A conference presentation based on most of these results was given in May. Subsequent activity during 1993 was primarily directly towards filling in gaps, and developing a research paper based on this work.

CONFERENCE PRESENTATION: Brown, D.G., "An Evaluation of Two Common Inventory-Theoretic Procedures for Freight Service Choice Problems," TIMS/ORSA Joint National Meeting, Chicago, IL, Spring 1993.

OTHER: The investigator is preparing a paper based on these results for submission to a refereed research journal in early 1994.

DOD KEY TECHNOLOGY AREA: Other.

KEYWORDS: Freight Service Quality, Inventory-theoretic, Model Validation.

**DETAILED TRACK INSPECTION PROCEDURES TO SUPPORT
MAINTENANCE MANAGEMENT OF U.S. ARMY RAILROAD NETWORKS**

**D.G. Brown, Visiting Assistant
Department of Systems Management
(Unfunded at NPS)**

OBJECTIVE: The goal of this project was to continue the development of detailed track inspection procedures designed to support maintenance management of U.S. Army railroad networks, and to effectively communicate these procedures to potential users.

SUMMARY: RAILER is a decision-support system for the maintenance management of railroad networks developed at the U.S. Army Construction Engineering Research Laboratory (USACERL). The RAILER detailed inspection procedures have been undergoing continuous development over the last 8 years with several iterations of feedback from users and other interested parties. These procedures were finalized during 1992 and 1993 in conjunction with the most current release of RAILER. Because this investigator had been deeply involved

in the development of these procedures and their earlier documentation, his input was solicited for this final work. The principal activity for this investigator during 1993 was reviewing the Draft Army Technical Report describing these inspection procedures he had revised in 1992. The final report, to be issued in the near future, is designed to provide guidance for inspectors in the field.

OTHER: A second draft technical report was issued this year. The final report should be published in 1994.

DOD KEY TECHNOLOGY AREA: Other.

KEYWORDS: Railroad Track Inspection Procedures, Maintenance Management, Condition Evaluation, Decision Support.

**GRAPHICAL USER INTERFACE DESIGN OF THE MILSATCOM DECISION
SUPPORT SYSTEM**

**T.X. Bui, Associate Professor
M.N. Kamel, Associate Professor
Department of Systems Management
Sponsor and Funding: U.S. Space Command**

OBJECTIVE: The objective of this project is to develop a prototype decision support system (DSS) to measure the trade-off between military satellite communications capabilities and user requirements for those capabilities. This effort requires the integration of several DSS's and their associated databases into a user-friendly comprehensive system.

SUMMARY: Requirements analysis for the proposed system was performed and the critical success factors were determined. Based on the requirements, the graphical user interface displays for the DSS were designed and implemented. A new conceptual design for the MILSATCOM Requirements Database was developed and transformed into a relational schema. In addition, a comparative performance analysis was conducted to examine the trade-offs between normalization and performance. Finally a prototype PC-based graphical database application to manage military satellite communication resources was developed.

THESES DIRECTED: Henry, H. A., MAJ, USMC, "Military Satellite Communications Decision Support System Requirements Analysis and User Interface Design," Master's Thesis, June 1993.

Kearns, R.G., CAPT, USAF, "A Conceptual Database Design and Performance Analysis of the MILSATCOM Requirements Database," Master's Thesis, June 1993.

Major, W.M., CAPT, USAF, "Design and Implementation of a Prototype PC Based Graphical and Interactive MILSATCOM Requirements Database System," Master's Thesis, June 1993.

OTHER: A prototype PC-based graphical database application system to manage military satellite communications (MILSATCOM) resources.

DOD KEY TECHNOLOGY AREA: Software.

KEYWORDS: Database Systems, Decision Support Systems, Graphical User Interface.

DEPOT MAINTENANCE RESOURCE PREDICTION MODEL SYSTEM
VALIDATION, REFINEMENT, AND ENHANCEMENT

D.R. Dolk, Professor

S.S. Liao, Professor

D.C. Boger, Professor

M.H. Ackroyd, Associate Research Professor

Department of Systems Management

Sponsor and Funding: Strategic Logistics Agency

OBJECTIVE: The purpose of this project is to review and analyze the existing version of PMSDA's Depot Maintenance Resource Prediction Model (DMRPM) for possible refinement and enhancement. The research will use data related to combat vehicles to identify and validate the resource predictive algorithms, and to identify additional decision needs to current users and areas for refinements. The DMRPM software program will be evaluated and validated with respect to the suitability of its architecture. This project is currently in progress.

SUMMARY: Algorithms for the DMRPM

have been documented in meetings with the sponsor and associated subcontractors. An object-oriented model of depot maintenance is being developed from this documentation. Black-box and white-box testing area currently underway to validate that those algorithms have been implemented correctly within the DMRPM program.

DOD KEY TECHNOLOGY AREA: Computers, Software.

KEYWORDS: Model Management, Object-oriented, Depot Maintenance, Algorithm Validation.

NAVAL POSTGRADUATE SCHOOL RESEARCH SUPPORT FOR THE
ARMY STRATEGIC LOGISTICS AGENCY

D.R. Dolk, Professor

G.W. Thomas, Associate Professor

Department of Systems Management

Sponsor and Funding: Army Strategic Logistics Agency

OBJECTIVE: The Strategic Logistics Agency is responsible for performing design, analysis and testing to determine the most efficient methods for modernization of the supply, maintenance, transportation, provisioning, distribution, and service functions of existing and emerging logistics automation systems. The goal of this research was to provide management for this umbrella research project between NPS and SLA.

SUMMARY: Proposals were solicited, evaluated, and passed to SLA for their evaluation. Three projects were selected for funding:

(1) Prof. Rick Rosenthal (OR): Research and Development Capital Budgeting.

(2) Profs. Boger and Liao (SM): Assessment of Depot Maintenance Models.

(3) Prof. Dolk (SM): Model Integration of Depot Maintenance Computer Models.

DOD TECHNOLOGY AREA: Computers, Software, Communications Networking.

KEYWORDS: Research, Logistics, Models.

MILITARY SATELLITE REQUIREMENTS DATABASE

D.R. Dolk, Professor
T.X. Bui, Associate Professor
M. Kamel, Associate Professor
Department of Systems Management
Sponsor and Funding: U.S. Space Command

OBJECTIVE: The purpose of this research was to provide design assistance for the development of a Military Satellite Decision Support System (MDSS).

SUMMARY: Two components were considered for design development: the military requirements database (MRDB) and the user interface for MDSS. A new conceptual schema was developed for the MRDB using the Entity-Relationship model and transformed into a relational schema for implementation (Thesis 1). An implementation of the MRDB was carried out using the Microsoft Access database system (Thesis 2). Graphical user interfaces were designed to support the spectrum of functions for the overall MDSS.

THESES DIRECTED: Kearns, Ronald G., CAPT, USAF, "A Conceptual Database Design and Performance Analysis of the MILSATCOM Requirements Database," Master's Thesis, June 1993.

Major, William, M., CAPT, USAF, "Design and Implementation of a Prototype PC Based Graphical and Interactive MILSATCOM Requirements Database System," Master's Thesis, June 1993.

DOD KEY TECHNOLOGY AREA: Computers, Software.

KEYWORDS: Graphical User Interface, Database Management System, Military Satellites.

**THE USE OF ADA FOR THE IMPLEMENTATION OF AUTOMATED INFORMATION
SYSTEMS WITHIN THE DEPARTMENT OF DEFENSE**

J.C. Emery, Professor

D. Zweig, Research Assistant Professor

Department of Systems Management

**Sponsor and Funding: Dr. Michael J. Mestrovich, Director,
Office of Technical Integration & Interoperability, OSD**

OBJECTIVE: This project examined the use of the programming language Ada for developing Automated Information Systems (AIS) within DoD, giving consideration to alternative languages and approaches for application software development.

SUMMARY: We have concluded that Ada often does not provide the most cost-effective approach to AIS development, and that therefore greater discretion should be granted to project managers to use the most cost-effective approach for their particular applications (within general guidelines and standards). Our analysis concludes that AIS-specific languages, rather than a general-purpose, third-generation language such as Ada, generally provide substantial gains in development productivity. A new software development paradigm is emerging, which conflicts with the

use of Ada in some important respects (such as an adaptive, evolutionary process).

OTHER: Emery, J.C. and D. Zweig, "The Use of Ada for the Implementation of Automated Information Systems within the Department of Defense," 28 December 1993, p. 33, (internal working paper).

A seminar on the topic is being given at Stanford University on January 14, 1994; further presentations are expected, as well as preparation of a paper for publication in the open technical literature.

DOD KEY TECHNOLOGY AREA: Computers, Software.

KEYWORDS: Software Development, Automated Information Systems, Ada.

ANALYSIS OF THE MANAGEMENT CONTROL RAMIFICATIONS

K.J. Euske, Professor

Department of Systems Management

Sponsor and Funding: Commander, Naval Supply Systems Command

OBJECTIVE: This is a continuation of part of a previous research project. The specific objective of this research project is to:

(1) Analyze the current management control system currently in place to support the RAMP project.

(2) Recommend adjustments to that system such that the output of the system will provide information that accurately appraises the RAMP project.

(3) Ensure that the system provides valid and reliable information regarding the cost, effectiveness, and efficiency of the RAMP project.

The RAMP Project within the Navy is concerned with developing highly

automated manufacturing facilities using advanced robotics.

Release time: One quarter.

THESES DIRECTED: Peterson, Marlene, "A Management Case Study: The Implementation of the Rapid Acquisition of Manufactured Parts (RAPM), Master of Science of Management, March 1993.

Spence, Frank, "Activity-Based Costing in a Service, Master of Science of Management, June 1993.

DOD KEY TECHNOLOGY AREA: Other.

KEYWORDS: Computer Integrated Manufacturing, Activity-based Costing, Lean Manufacturing.

IMPROVING THE PROCESS IMPROVEMENT PROCESS

K.J. Euske, Professor

W. Haga, Professor

Department of Systems Management

Sponsor and Funding: Office of the Director of Defense Information

OBJECTIVE: The purpose of this project was to develop a database on benchmarking and re-engineering resources for the Office of the Director of Defense Information (DDI). This project supported the re-engineering of DoD business functions and processes. The long run goal is to have a benchmarking database for use by DoD, other federal and non-federal government organizations, and industry. Such a database will have at least two major benefits: First, it will be a means for the U.S. Government to use the resources furnished by the taxpayers more effectively and efficiently. Second, it will be a resource to support the U.S. industrial base.

Release time: One and one-half quarters.

SUMMARY: The project developed the REAP database in Oracle for IBM-compatible PCs and populated it with demonstration data on best practices, experts and metrics for business processing re-engineering.

CONFERENCE PRESENTATION: Euske, K.J. and Haga, W.J., "Process for Improving Processes: Elements and Issues," Consortium for Advanced Manufacturing International-Cost Management System Program, San Diego, CA, March 1993.

Euske, K.J. and Lebas, M.J., "Performance Measurement for Maintenance Depots," Bridging the Gap Conference, Babson College, 25-26 June 1993.

Euske, K.J., Lebas, M.J., and McNair, C.J., "Management of Performance in

An Industrial Setting: A Survey of Current Practice," The 16th Annual Congress of the European Accounting Association, Turku, Finland, 28-30 April 1993. (Earlier version presented at The Second European Management Control Symposium, H. E. C. School of Management, 9-11 July 1992).

THESES DIRECTED: Shivers, Carol E., "Marshaling and Acquiring Resources for the Process Improvement Process," Master of Science in Management, June 1993.

Young, Dan H., "Business Process Redesign: Creating an Environment for Discontinuous Thinking," Master of Science in Information Technology Management, September 1993.

Ritter, Kenneth C., "Implementing Change: A Guide for the DoD Functional Manager," Master of Science in Information Technology, September 1993.

Warwick, Jerry L., "Business Process Redesign: Design the Improved Process," Master of Science in Information Technology Management, September 1993.

Steckler, Kathleen M., "Naval Air Station Cubi Point: A 'Hot Turnover'? A Management Case Study," Master of Science in Management, September 1993.

Phillips, Varanda K., "An Application of an IDEF0 Model to Improve the Process of Base Closure: A Case Study," Master of Science in Management, December 1993.

Horsley, Arthur B., "A Model for Evaluating Vendor Proposals for Price and Lead Time, Master of Science in Management, December 1993.

DOD KEY TECHNOLOGY AREA: Other.

KEYWORDS: Benchmarking, Process Re-engineering.

IDENTIFYING COST EFFECTIVE DOD DRUG DEMAND REDUCTION PROGRAMS

W.R. Gates, Visiting Assistant Professor

K.L. Terasawa, Visiting Professor

Department of Systems Management

Sponsor and Funding: Bureau of Naval Personnel (PERS-63E)

OBJECTIVE: This is the first phase of an effort to help develop a cost-effective mix of drug demand reduction programs in DoD. The objective is to identify the characteristics of the at-risk population and design specific initiatives to efficiently address that population.

SUMMARY: This project focused on three primary areas, as follows.

Survey the literature and gather available data on military drug abuse to (a) construct a statistical drug abuse profile for the U.S. military, by service and (b) identify military drug demand reduction efforts, by service.

Analyze civilian sector drug abuse to (a) construct a statistical drug abuse profile for the U.S. civilian population and (b) identify drug demand reduction efforts in the civilian sector.

Analyze the costs of drug abuse in

the Navy, including the costs of testing, rehabilitation (treatment and lost work hours) and personnel replacement.

The current task was intended as a feasibility study, to understand the nature of the problem and identify the data available for a detailed follow-on study.

THESES DIRECTED: Erb, Katherine D.C., LT, USN, "Updated Cost Effectiveness Analysis of the Navy Drug and Alcohol Rehabilitation Program," Master's Thesis, December 1993.

Lewis, Samuel W., LT, USN, "A Cost Analysis of a Navy Drug Abuse Education Program," Master's Thesis, December 1993.

DOD KEY TECHNOLOGY AREA: Other.

KEYWORDS: Drug Abuse, Drug Prevention, Drug Education.

POTENTIAL MILITARY RIVALS:
TECHNOLOGICAL, ECONOMIC AND OPERATIONAL CONSIDERATIONS

**G.G. Hildebrandt, Visiting Associate Professor
Department of Systems Management**

Sponsor and Funding: OSD (Net Assessment)

OBJECTIVE: The analysis investigated issues associated with the maintenance of U.S. military-technological superiority into the twenty first century.

SUMMARY: The project provided estimates of the costs facing military rivals to the United States wishing to field a Reconnaissance-Strike Complex (RUK) like that employed in the Gulf War of 1991. The hypothetical rivals chosen were the People's Republic of China and a post-NATO European coalition centered on France, Germany, and the United Kingdom. The cost estimates indicate Europe could field a RUK with relatively modest adjustments and increases to current defense efforts. On the other hand, acquiring and operating a RUK is a major task for

the PRC, and would impose substantial burdens -- comparable to those that could be anticipated for the United States undertaking a large SDI program.

OTHER: Research findings were summarized in Franck, R. and Hildebrandt, G., "Potential Military Rivals: Some Technological, Economic and Operational Considerations," October 1993.

Also, the investigators are preparing an article for submission to an academic journal.

DOD KEY TECHNOLOGY AREA: Other.

KEYWORDS: Reconnaissance-Strike Complex (RUK).

MILITARY DECISION MAKING

C.R. Jones, Professor of C3 and Systems Management
N.C. Roberts, Associate Professor of Strategic Management and C3
K. Sengupta, Assistant Professor of Information Systems
Department of Systems Management
Sponsor: Naval Oceans Systems Center, San Diego
Funding: Naval Postgraduate School

OBJECTIVE: The goal of this project is to investigate how individuals, groups, and organizations make decisions in military and DoD related contexts at both the strategic and operational levels and to make recommendations for improvement.

SUMMARY: This research cautions against the transfer of "lessons learned" from business decision making research and practice to organizations like the DoD/DoN with their special missions and mandates. Decision making in strategic and operational settings, especially under combat conditions, requires a decision approach geared to these unique contexts and situations.

PUBLICATIONS: Jones, C., Sengupta, K, and Roberts, N.C., "A Conceptual Framework for a Combat Organization's Command and Control Systems of Systems," in Proceedings of the JDL Conference on Command and Control, National Defense University, Washington, DC, June 1993.

Roberts, N.C., "Limitations of Strategic Action in Bureaus: The Case of the Department of Defense," in Public Management: The State of the Art, Barry Bozeman, ed., San Francisco: Jossey-Bass, pp. 153-172, 1993.

CONFERENCE PRESENTATIONS: Jones, C., Sengupta, K., and Roberts, N., "A Conceptual Framework for a Combat Organization's Command and Control System of Systems," 1993 Symposium on Command and Control Research, Nation-

al Defense University, Washington, DC, 28 June-1 July 1993.

Roberts, N., "Dialogue and Deliberation: A New Mode for Crafting Strategy," Berkeley Symposium on Public Management Research, 19 July 1993, University of California, Berkeley, co-sponsored by the Research Division of the American Society for Public Administration, the Graduate School of Public Policy of the University of California, Berkeley, and the Journal of Public Administration Research and Theory.

Roberts, N.C. and Wargo, L., "Compensating for Size: Strategic Planning in the Department of the Navy," National Public Management Research Conference, University of Wisconsin, Madison, 30 September - 2 October 1993.

Bradley, R. and Roberts, N.C., "Relations of Affect and Control and Organizational Function," Academy of Management Meeting, Atlanta, GA, 6-11 August 1993.

THESES DIRECTED: Carter, J., "Information Management in a Joint Task Force," Masters of Science in Systems Technology (C3), June 1993, (Advisor: Jones, C.).

Carr, M., "A Heuristic to Formulate Rules of Engagement," Masters of Science in Systems Technology (C3), June 1993, (Advisor: Jones, C.).

Myrick, P.R., "A Case Study of Successful Program Management: PM Army

Tactical Missile Systems." Masters of Science in Management, March 1993, (Advisor: Roberts, N.).

Stream, C. K., "Alternative Dispute Resolution: How the Department of the Navy Can Benefit From the Use of Mini Trials," Masters of in Management, June 1993, (Advisor: Roberts, N.).

Eaton, C., "An Economical and Cost Benefit Analysis of Alternative Dispute Resolution Methods in Settling Government Contract Disputes," Masters of Science in Management, June 1993, (Advisor: Roberts, N.).

Carpenter, D.K. and Ebner, D.J., "Using Software Applications to Facilitate and Enhance Strategic Planning," Masters of Science in Information Science, September 1993, (Advisor: Roberts, N.).

Dennison, P., "A Case Study of the USS Dwight D. Eisenhower Collision and Its Implications," Masters of Science in Management, September 1993, (Advisor: Roberts, N.).

Turner, L.L., "Conducting a Successful Operational Test -- What Program Officers Should Know," Masters of Science in Management, September 1993, (Advisor: Roberts, No.).

Williamson, E., "Lessons Learned in Drawdowns," Masters of Science in Management, September 1993, (Advisor: Roberts, N.).

Walsh, D., "Contracting Support for Army Special Forces," Masters of Science in Management, December 1993, (Advisor: Roberts, N.).

Bergeron, Wayne, "Re-engineering Acquisition," Masters of Science in Management, December 1993, (Advisor: Roberts, N.).

Robinson, R. and Swenson, B., "Innovation and Entrepreneurship in Logistical Support: A Case Study," Masters of Science in Management, December 1993, (Advisor: Roberts, N.).

Carter, Donald K., "Department of the Army Field Contracting Activities' Contracting Efforts with the Federal Prison Industries, Inc.," Masters of Science in Management, December 1993, (Advisor: Roberts, N.).

Irick, Ronald P., "Evaluation of Public-Private Competition in NADeps," Masters of Science in Management, December 1993, (Advisor: Roberts, N.).

Rutledge, S., "Comparative Efficacies of Decision Strategies and the Effects of Learning in Dynamic Environments: A Computer Simulation Approach," Masters of Science in Information Technology Management, September 1993, (Advisor: Sengupta, K.).

Elser, E., "The Impact of Multiple Objectives in Dynamic Decision Making," Masters of Science in Information Technology Management, September 1993, (Advisor: Sengupta, K.).

OTHER: Roberts, N., "Dialogue and Deliberation: A New Mode for Crafting Strategy," submitted to Human Relations.

Dotterway, K. and Roberts, N., "The Vincennes Incident: Another Player on the Stage," submitted to Armed Forces and Society.

Roberts, N.C. and Wargo, L., "Compensating for Size: Strategic Planning in the U.S. Navy," submitted to Strategic Management Journal.

Sengupta, K. and Elser, E., "The Impact of Multiple Objectives in

Dynamic Decision Making," in preparation.

DOD KEY TECHNOLOGY AREA: Human-System Interfaces.

KEYWORDS: Military Decision Making, Organized Decision Processes, Data Fusion, Command and Control.

NAVY SHIP MAINTENANCE AND REPAIR AND
THE IMPACT OF BUDGET REDUCTION

L.R. Jones, Professor

Department of Systems Management

**Sponsor: Kenneth Jacobs, Director, Ship Maintenance and
Repair Division, NAVSEA**

Funding: NAVSEA

OBJECTIVE: The goal of this project was to assess the roles, participants and relationships in the Navy system for Ship Maintenance and Repair and to analyze methods for improving the efficiency and cost-effectiveness of this system. Selected issues in programming and budgeting for ship maintenance and repair also were examined. The goals and funding for this project were provided late in FY 1991 and continued into FY 1993.

SUMMARY: Research was performed in NAVSEA and in PACFLT and LANTFLT to assess the characteristics of the Navy ship maintenance and repair system. This system was analyzed in terms of the roles of the participants and their relationships in the work preparation and documentation process for Navy ship repair and maintenance. The work preparation system was described and analyzed for methods and alternatives to improve efficiency and cost-effectiveness. Preliminary results were presented to the sponsor and feedback was obtained on approaches to further analyze. The climate and characteristics of the POM and budget preparation were assessed with the assistance of the sponsor to assist in the design of further research.

CONFERENCE PRESENTATION: Jones, L.R., Association for Budgeting and Financial Management, American Society for Public Administration, panel

chair, "International Budget and Finance Experience: Fiscal Policy and Culture," and paper presentation, "Fiscal Policy and Retrenchment in Switzerland," Arlington, VA, October 1993.

THESES DIRECTED: Palmer, Michael A., "A Comprehensive Analysis of the Maintenance Requirements System," Masters of Science in Management, June 1993.

Erhlich, Daniel, "Surface Ship Maintenance in the Corporate Environment and the Navy," Masters of Science in Management, June 1993.

Kemper, Verne, (Conrad Scholar), "A Financial Analysis of the COBRA Model," Masters of Science in Management, December 1993.

Keller, Joseph A., "Issues Facing Navy Contracting Organizations in Implementing OFFP Policy Letter 92-4," Masters of Science in Management, December 1993.

DOD KEY TECHNOLOGY AREA: Other.

KEYWORDS: Surface Ship Maintenance, Financial Analysis.

**NAVY FLEET AND FLIGHT HOUR BUDGETING AND IMPACT OF DMR AND
BUDGET REDUCTION**

**L.R. Jones, Professor
Department of Systems Management
Sponsor and Funding: COMNAVAIRPAC**

OBJECTIVE: The goal of this project was to assess the budget and the impact of budget reductions in the AIRPAC, PACFLT command, to assess management control system and accounting changes to respond to budget austerity including those related to the DMR process and to analyze US-Japan national defense resource burdensharing.

SUMMARY: Research was performed in the field in AIRPAC HQ and installations to assess the characteristics of budget and accounting systems. These systems were analyzed in terms of the roles of the participants and their relationships in budget preparation, analysis and justification. The budget preparation system was analyzed for methods and alternatives to improve efficiency and cost-effectiveness. Preliminary results were presented to the sponsor and feedback was obtained on approaches to further analysis. The climate and characteristics of the POM and budget preparation were assessed with the assistance of the sponsor to assist in the design of further research. Characteristics of US-Japanese defense resource burdensharing also were examined from a budgetary, political and economic perspective.

PUBLICATIONS: Jones, L.R. and McCaffery, J., "Symposium on Federal Financial Management Reform, Part II," Public Budgeting and Finance, 13 January 1993.

Jones, L.R. and McCaffery, J., "Implementation of The Chief Finan-

cial Officer Act," Public Budgeting and Finance, 13 January 1993.

Jones, L.R., "Counterpoint Essay: Nine Reasons Why the CFO Act May Not Achieve It's Objectives," Public Budgeting and Finance, 13 January 1993.

Jones, L.R., "Management of Budgetary Decline in the Department of Defense in Response to the End of the Cold War," Armed Forces and Society, 19 April 1993.

CONFERENCE PRESENTATION: Jones, L.R., "Misrepresentation as an Element of Budget Strategy and Control," Association for Budgeting and Financial Management National Conference, Arlington, VA, October 1993.

THESES DIRECTED: Dawe, Richard, "Analysis of Base Realignment and Closure: The Example of NAS Whidbey Island," Master's Thesis, December 1993.

Kane, Michael, W., "Hazardous Waste Reduction Efforts of the Navy and DoD in the San Diego, California Region," Master's Thesis, December 1993.

Robinson, David M., "A Report on Base Reuse Planning at the Tustin Marine Corps Air Station," Master's Thesis, December 1993.

DOD KEY TECHNOLOGY AREA: Other.

KEYWORDS: Base Realignment, Base Closure, Base Reuse, Hazardous Waste Management.

**IMPACT OF DMR AND BUDGET REDUCTION AND DOD FM EDUCATION
ASSESSMENT**

L.R. Jones, Professor
Department of Systems Management
Sponsor: Comptroller, DoD
Funding: Naval Postgraduate School

OBJECTIVE: The goal of this project was to assess the impact of budget reductions in DoD including those related to the DMR process and to conduct a survey of quality assessment in DoD Financial Management Education and Training Institutions.

SUMMARY: Research was performed to assess budget and DMR processes and reductions. These were analyzed in terms of the roles of the participants and their relationships. The budget system was analyzed for methods and alternatives to improve efficiency and cost-effectiveness. Preliminary results were presented to the sponsor and feedback was obtained on approaches to further analysis. The climate and characteristics of the budget preparation were assessed with the assistance of the sponsor to assist in the design of further research. The impact of the DMR in DoD was assessed. A survey of quality assessment methods in DoD Financial Management Education and Training Institutions was conducted and reported to the DoD Comptroller and staff to follow up on a part of DMR 985.

PUBLICATIONS: Jones, L.R. and McCaffery, J., "Symposium on Federal Financial Management Reform, Part II," Public Budgeting and Finance, 13 January 1993.

Jones, L.R. and McCaffery, J., "Implementation of The Chief Financial Officer Act," Public Budgeting and Finance, 13 January 1993.

Jones, L.R., "Counterpoint Essay: Nine Reasons Why the CFO Act May Not Achieve its Objectives," Public Budgeting and Finance, 13 January 1993.

Jones, L.R., "Management of Budgetary Decline in the Department of Defense in Response to the End of the Cold War," Armed Forces and Society, 19 April 1993.

DOD KEY TECHNOLOGY AREA: Other.

KEYWORDS: Defense Management, Federal Financial Management, Chief Financial Officer Act.

**RESEARCH ISSUES IN THE DEPARTMENT OF NAVY DATA
ADMINISTRATION PROGRAM**

**M.N. Kamel, Associate Professor
Department of Systems Management
Sponsor and Funding: Naval Postgraduate School**

OBJECTIVE: The objective of this project is to conduct research and provide technical advice to the following tasks in order to meet the goals of the Corporate Information Management (CIM) initiative and the DoN Data Administration Program: 1) Data modeling; 2) Survey of DoD Data Administration; 3) Migration strategy for data dictionaries/repositories; and 4) Evaluation criteria for data dictionaries/repositories.

SUMMARY: This project integrated subject area data from three different but overlapping databases and created a strategic level integrated data model. In addition this effort developed a comprehensive framework for identifying and classifying semantic heterogeneity using both the entity relationship and the object-oriented data models as the integrating data model. Possible solution strategies were

offered for each type of conflict identified in the framework. These solutions were applied to the realize the strategic level integrated data model.

THESES DIRECTED: Bourque, M.T., "A Framework for Classifying and Resolving Semantic Heterogeneity in Object-Oriented Databases," Master's Thesis, September 1992.

Lindsey, D.A., "A Framework for Classifying and Resolving Semantic Conflicts using the Enhanced Entity-Relationship Model," Master's Thesis, September 1992.

DOD KEY TECHNOLOGY AREA: Software.

KEYWORDS: Data Administration, Data Modeling, Data Integration, Semantic Conflict Identification and Resolution.

COST PER OUTPUT ANALYSIS FOR USAREC

K. Kang, Associate Professor

K.L. Terasawa, Visiting Associate Professor

Department of Systems Management

Sponsor and Funding: U. S. Army Recruiting Command (USAREC)

OBJECTIVE: The objective of this research is (1) to develop a transparent and documentable cost per output methodology for the US Army recruiting activities; and (2) to identify the areas for cost-savings with the future changes in recruiting environment.

SUMMARY: Our study of USAREC's unit costing revealed several potential problems. By simply dividing the total expenditure by the number of accessions will not provide meaningful cost information. Unit costing is based on variable costs. By far, the majority of USAREC's costs are fixed. When the number of accessions are reduced, the overhead structure must be re-examined to determine efficient allocation of resources. USAREC does not have spending discretion over 70% of their expenditures. Without spending authority and responsibility, managers may have little incentive to reduce costs and the ones they can reduce are overshadowed by what they do not control. The largest of the "big ten" categories, Military Personnel Army (MPA) account, may actually be undercharged as much as 20%. The MPA expenditure is determined by multiplying the TDA (Table of Distribution and Allowances) by a DA composite cost for officers and one for NCOs. The composite cost does not take into account the "top heavy" structure of USAREC. Also, since it is based on the TDA, any personnel shortages or

overages are not reflected in the expenditures. This condition might actually encourage managers to overfill slots since they are not charged the extra personnel cost. Also, facilities are charged a flat percent of the Services recruiting facilities expenditures. All the services would have to withdraw from a leased facility before USAREC would realize any cost savings. They are charged whether they use the facility or not.

We also examined the possibility of implementing a bonus incentive system for recruiters. The current quota system may possess potential inefficiencies. The bonus system would help maximize market potential and help USAREC in the efficient allocation of resources. Recruiters would be rewarded on how well they forecasted and on the number of accessions achieved.

OTHER: Terasawa, K.L. and Kang, K., "Efficient Recruiting Incentive System," in preparation.

THESIS DIRECTED: Lyons, S. and Riester, B., "Cost per Output for USAREC," Master's Thesis, December 1993.

DOD KEY TECHNOLOGY AREA: Other.

KEYWORDS: Recruiting, Cost per Output, Life-Cycle Cost, Decision-support.

COST PER OUTPUT ANALYSIS FOR U. S. ARMY RESERVE

K. Kang, Associate Professor

K.L. Terasawa, Associate Visiting Professor

Department of Systems Management

Sponsor and Funding: U. S. Army Recruiting Command (USAREC)

OBJECTIVE: The objective of this research is (1) to develop a framework to find the best mix of prior service and non-prior service enlisted accession (NPS/PS mix) that minimizes the life-cycle cost for the US Army Reserve (USAR) over a period of time; and (2) to develop a transparent and documentable cost per output methodology for the USAR recruiting activities. The results of this research will provide the decision-maker at the USAR with a decision support tool for policy making.

SUMMARY: Our study of U. S. Army Recruiting command's (USAREC's) unit costing revealed several potential problems. Currently USAREC calculates two unit cost figures for recruiting: one for the Regular Army and another for the Army Reserve by simply dividing the total expenditures by the number of accessions. These figures will not provide meaningful cost information. This project is concurrently conducted with the Regular Army cost study. Compare to Regular Army study, this study is more complicated because of Reserve's unique characteristics. High attrition rates in the reserve force is a significant problem. Seventy percent of reserve soldiers do not complete their six year enlistment contract. Separation from

the reserve unit before completion of the contractual term of service lowers readiness while increases training and recruiting costs.

Army reserve recruits are classified as non-prior service (NPS) -- those without prior military training and experience -- and as prior service (PS) -- individuals who have served in the active or reserve forces. The advantage of recruiting NPS over PS is the lower salary, the greater flexibility in MOS-matching, and the higher probability of longer service with the Reserve. However, these advantages must be weighed against its inherently higher training costs and potentially lower readiness level. We are currently collecting data on attrition rates and related costs factors to develop a life cycle cost framework and determine the PS/NPS mix that minimizes the cost over time. Such a mix would be influenced not only by the changes in recruiting/training costs but also by the changes in end-strength target.

DOD KEY TECHNOLOGY AREA: Other.

KEYWORDS: Recruiting, Cost per Output, Life-Cycle Cost, Decision-support, Army Reserve, Prior-service.

CONTRACTING TAXONOMIES

**D.V. Lamm, Associate Professor of Systems Management
Department of Systems Management
Funding: Unfunded**

OBJECTIVE: This project is a continuing effort to identify and examine various characteristics of the contracting profession through the development and use of the taxonomical approach.

SUMMARY: In order to research the acquisition and contracting profession, rigorous classification of significant characteristics must be accomplished. The premise that Federal Government goods exhibit elements that can be used from a strategic sense in the buying process led to an attempt to identify and classify these elements. Through a panel of experts a theoretical structure was established. Questionnaires were used to obtain data for classification purposes. A model classification scheme was developed as the basis for further investigation. A second study was undertaken to examine homogeneous goods with specific sets of buyers. The study has also been expanded to include services purchased by the Federal Government. A third study was undertaken to examine the practical applications and benefits that can be gained through use of the taxonomy. This is a continuing research effort.

PUBLICATION: Lamm, D.V., Prendergast, J., Wenger, B., and Sheehan, E., "Application of a Taxonomical Structure for Classifying Federal Government Goods," in Proceedings of the 1993 Acquisition Research Symposium, pp. 409-420, June 1993.

CONFERENCE PRESENTATION: Lamm, D.V., and Prendergast, J., "Application of a Taxonomical Structure for Classifying Federal Government Goods," Acquisition Research Symposium, Rockville, MD, 22 June 1993.

THESES DIRECTED: Sheehan, E.W., "A Taxonomy of Goods Procured by the Federal Government: Applications and Benefits," Master's Thesis, December 1992.

Beeson, K., "Expanded Applications and Benefits of a Taxonomy of Goods Procured by the Federal Government," Master's Thesis, June 1993.

DOD KEY TECHNOLOGY AREA: Other.

KEYWORDS: Taxonomy, Procurement, Acquisition, Purchasing, Contracting.

DEFINITIONS OF CONTRACTING TERMS

**D.V. Lamm, Associate Professor
Department of Systems Management
Funding: Unfunded**

OBJECTIVE: The objective of this project was, and continues to be, the development of a dictionary of contracting terms.

SUMMARY: The contracting profession has been criticized over the past several years for the lack of clear definitions for a number of its terms. Beginning in 1988, NPS and the Air Force Institute of Technology (AFIT) have collaborated on a project to develop a dictionary of contracting terms to be used by the profession. The work has been accomplished principally by graduate thesis students at both institutions in the contracting curricula. Approximately 500 terms have been earmarked for definition, and approximately 350 terms have been defined. The process involves a comprehensive review of the literature, including the Federal Acquisition Regulation (FAR), to determine how a term is currently defined and to develop a "working" definition. A survey questionnaire is used with selected experienced contracting professionals to obtain feedback concerning the terms use in practice. Responses are synthesized and a new proposed definition is presented. Terms are then published in

the Contract Management journal with an invitation to respond to the researcher regarding any recommended changes.

PUBLICATION: Lamm, D.V. and Pursch, W.C., "A Dictionary of Contracting Terms, Part III," Contract Management, Vol. 33, Issue 4, pp. 16-21, 23 April 1993.

THESES DIRECTED: Zarou, M.M., "A Dictionary of Acquisition and Contracting Terms," Master's Thesis, December 1992.

Omechevarria, G.L., "A Dictionary of Acquisition and Contracting Terms," Master's Thesis, December 1992.

Furforo, M.S., "A Dictionary of Acquisition and Contracting Terms," Master's Thesis, December 1992.

Hayes, S.T., "A Dictionary of Acquisition and Contracting Terms" Master's Thesis, December 1992.

DOD KEY TECHNOLOGY AREA: Other.

KEYWORDS: Acquisition, Procurement, Definitions, Contracting, Purchasing.

CONTRACT NEGOTIATIONS

D.V. Lamm, Associate Professor
Department of Systems Management
Funding: Unfunded

OBJECTIVE: The focus of this research was to examine use of the simulated negotiation method in preparation for contract negotiations.

SUMMARY: This research examined the effect on a negotiated outcome if buyers engage in preparatory simulated negotiations. If it is found that simulated negotiations result in a significantly improved outcome during actual negotiation, then the conduct of such preparatory simulated negotiations could enhance negotiator effectiveness. One hundred and thirty nine negotiations involving DOD buyers, industry contractors, and graduate students were conducted. The data collected from these negotiations included the prices negotiated and a qualitative assessment based on the respondent's answers to a series of questions. Based on an analysis of these data, it was concluded that buyers engaging in simulated negotiations improved the negotiation outcome. The study also reports the key differences

concerning the utility of simulated negotiations among the three test groups.

PUBLICATION: Lamm, D.V. and Bennett, R., "Simulated Negotiations: A Measure of Their Effectiveness on Negotiated Outcome," in Proceedings of the 1993 Acquisition Research Symposium, pp. 421-431, June 1993.

CONFERENCE PRESENTATION: Lamm, D.V. and Bennett, R., "Simulated Negotiations: A Measure of Their Effectiveness on Negotiated Outcome," Acquisition Research Symposium, Rockville, MD, 23 June 1993.

THESIS DIRECTED: Besch, T.M., "Identification of Negotiation Tactics and Strategies of Army Negotiators," Master's Thesis, December 1992.

DOD KEY TECHNOLOGY AREA: Other.

KEYWORDS: Contracting, Negotiations, Acquisition.

IN SUPPORT OF N1/BUPERS

**S.L. Mehay, Professor
M. Eitelberg, Associate Professor
Department of Systems Management**

**Sponsor and Funding: Deputy Chief of Naval Operations (MPT)
N1/BUPERS, Washington, DC**

OBJECTIVE: This project provided an umbrella funding within which individual projects were proposed and carried out by individual researchers. Mehay coordinated the overall project and facilitated interactions between individual MPT faculty and N1/BUPERS.

The two specific sub-projects were:

(1) "An analysis of the determinants of the decision by enlisted personnel to voluntarily separate from the Navy in response to the VSI/SSB bonus programs, and an analysis of the net effect of the program on retention;"

(2) "An analysis of the propensity for nontraditional occupations among women."

SUMMARY: (1) This project involved analyzing the acceptance decisions of enlisted Navy personnel eligible for the VSI/SSB voluntary separation bonuses. The project also conducted a quasi-experiment to determine the net effect of the separation bonus program on retention.

(2) This project analyzed data from various labor market surveys and navy surveys to determine occupational propensity among civilian women and the occupational distribution of women in the civilian labor force to identify patterns useful for predicting occupational choices among navy enlisted personnel.

OTHER: Mehay, S. and Hogan, P., "The Decision to Accept a Separation

Bonus: The Case of Military Personnel," Technical Report in process.

THESES DIRECTED: Kirby, Mary A., LT, USN, "A Multivariate Analysis of the Effects of the VSI/SSB Separation Program on Navy Enlisted Personnel," Masters of Science in Management, March 1993.

Noblit, Mark L., CAPT, USMC, "Forecasting VSI/SSB Take Rates for Enlisted Marine Corps Personnel," Masters of Science in Management, March 1993.

Giarizzo, Sal, LT, USN, "An Analysis of Enlisted Early Separations Under the Navy's VSI/SSB Program: The Impact of Eligibility and Program Benefits," Masters of Science in Management, December 1993.

Skocik, David J., CDR, USN, "A Longitudinal Analysis of the Acceptance Rates of the Navy's Voluntary Separation Incentive/ Special Separation Benefit Program," Masters of Science in Management, December 1993.

Brown, Marshall B., LT, USN, "An Analysis of the Propensity for Non-traditional Occupations Among Civilian and Navy Women," Masters of Science in Management, December 1993.

DOD KEY TECHNOLOGY AREA: Other.

KEYWORDS: Separation Bonus, VSI/SSB, Retention and Promotion.

RESYSTEMIZATION MODELLING SUPPORT

**A.W. McMasters, Professor of Operations Research and
Systems Management**

Department of Systems Management

Sponsor: Navy Supply System Command

Funding: None

OBJECTIVE: A continuing project to develop a Wholesale level inventory model for the Navy to use to replenish their inventories of repairable items; the objective function of this model should be related to readiness.

SUMMARY: A new inventory model for managing repairables at the Wholesale or Inventory Control Point (ICP) level is needed to determine when to replenish repairable items associated with a specific weapon system. This model should have the same objective function as the wholesale provisioning (or first buy quantity) model developed on this project between 1982 and 1986; namely, the minimization of the aggregate Mean Supply Response Time (MSRT).

Investigation of a realistic simulation model of the Navy's repairable inventory management process continued this past year, with the help of an OR thesis student, which allowed determination of the empirical time - weighted distributions for the

inventory position (IP) and the net inventory levels. This year's effort were concentrated on determining the distribution of net inventory and the relationship between the mean and variance of the net inventory distribution as a function of the various important parameters used by the Navy in its management of such items. The net inventory distribution was found to be normally distributed for the set of parameter values selected. A linear relationship was observed between the mean of the distribution and the product of the carcass return rate and repair survival rate.

THESIS DIRECTED: Maher, K. J., LT, SC, USN, "A Simulated Single-Item Aggregate Inventory Model for U. S. Navy Repairable Items," Master's Thesis, September 1993.

DOD KEY TECHNOLOGY AREA: Other.

KEYWORDS: Inventory Management, Repairable Items, Inventory Model.

**COST/EFFECTIVENESS ANALYSIS OF THE NAVAL AIRCRAFT ENGINE
COMPONENT IMPROVEMENT PROGRAM**

**A.W. McMasters, Professor of Operations Research and
Systems Management**

Department of Systems Management

Sponsor and Funding: Naval Air Systems Command

OBJECTIVE: A continuing project to develop models to predict the savings in life-cycle costs of proposed engineering changes intended to improve reliability, maintainability, and sustainability of turbine aircraft engines for Naval aircraft.

SUMMARY: An important element of aircraft logistical support is the aircraft engine Component Improvement Program (CIP). The CIP is essential for the continuing evolution of these engines. This project is looking for ways to justify that program. The first phase was to examine the current life-cycle cost models used by the Air Force and the Navy which are intended to show the expected savings from a specific proposed component improvement. NPS' evaluation of the Air Force's Cost Effectiveness Analysis Model (CEAMOD) has resulted in its replacing the Navy's in May 1993. The second phase is to validate the actual costs and logistics effectiveness of the CIP by looking at historical data. That may also suggest ideas for an improved model. A third phase was added this past year by the sponsor which addresses the problem of justifying warranties on aircraft engines.

A User's Manual for the Cost Effectiveness Analysis Model (CEAMOD) was developed for Version 2.0, the EXCEL version of the CEA model accepted by the Navy in May. Analysis of the effect of eliminating the integerization of certain calculations in the model was also conducted; no change in the decision to implement a CIP Engineering Change

Proposal was found. A break-through in the analysis of the J-52 engine was achieved with the analysis of the spline drive for the fuel pump. This was the first time an actual analysis was able to be completed to determine the cost/benefit of CIP funding and the expected saving in maintenance costs over the remaining life-cycle. The warranty study identified the fact that the Navy cannot be given replacement parts (because that would be a 'gift' to the government) nor can the repairing organization recover its costs since the vendor can only send the money to the Federal Treasury.

THESES DIRECTED: Andrews, M.S., LT, USN and Hickey, S.C., CPT, USA, "Analysis of Navy Aircraft Engine and Engine Component Warranties," Master's Thesis, December 1993.

Jones, M.A., LT, USN, "An Analysis of the Costs and Benefits in Improving the J52 Fuel Pump Main Gear Spline Drive under the Aircraft Engine Component Improvement Program," Master's Thesis, June 1993.

Rau, K.F., LCDR, SC, USN, "An Analysis of Non-Integerizing the Aircraft Engines Cost Effectiveness Analysis Spreadsheet Model (CEAMOD Version 2.0)," Master's Thesis, December 1993.

Reeves, R.R., LCDR, SC, USN, "A User's Manual for the Cost Effectiveness Analysis Spreadsheet Model for Aircraft Engines (CEAMOD Version 2.0)," Master's Thesis, December 1993.

DOD KEY TECHNOLOGY AREA: Other.

KEYWORDS: Naval Aircraft Engines,
Component Improvement Program (CIP),
Cost/benefit Analysis, Aircraft
Engine Warranties.

**INVESTIGATION OF COST PROGRESS
MODEL ACCURACY AND RELIABILITY**

**O.D. Moses, Associate Professor
Department of Systems Management**

Sponsor and Funding: Naval Postgraduate School

OBJECTIVE: This project continues the investigator's program of research on the performance of cost estimation/cost progress models. The goal of this year's effort was to assess the forecast accuracy and reliability of alternative cost prediction models.

SUMMARY: Cost progress models refer to a class of cost estimation models used to describe and forecast the pattern of costs expected during a repetitive production or procurement process. Different types and forms of cost progress models, such as learning curve models and production rate models, commonly used in DoD practice, were identified and selected for investigation. Cost data for a large sample of major military aerospace weapon system programs was collected.

The various different cost progress models were fit to the aerospace program cost data and then used to forecast future expected cost. Forecasted costs and actual realized costs were compared to measure forecast error, and quantify accuracy and bias, for each individual cost progress model. Different variables relating to forecasting conditions were identified. How the absolute and relative accuracy of the alternative

models depended on the forecasting conditions was documented.

PUBLICATIONS: Moses, O.D., "Error Patterns from Alternative Cost Progress Models," NPS Technical Report, NPS-AS-93-025, November 1993.

Moses, O.D., "On the Reliability of Indicators of Learning Curve Model Accuracy," Journal of Cost Analysis, 1993, forthcoming.

CONFERENCE PRESENTATIONS: Moses, O.D., "On Indicators of Cost Progress Model Accuracy," ORSA/TIMS National Meeting, Phoenix, AZ, November 1993.

Moses, O. D., "On the Reliability of Indicators of Learning Curve Model Accuracy," Society of Cost Estimating and Analysis, National Conference, Phoenix, AZ, June 1993.

OTHER: Papers reporting on this project's research results have been submitted to the Journal of Cost Analysis and the annual conference of the International Society of Parametric Analysts.

DOD KEY TECHNOLOGY AREA: Other.

KEYWORDS: Cost Progress Models, Learning Curves, Forecasting, Cost Estimation.

DESIGN RATIONALE CAPTURE AND REUSE
TO SUPPORT SYSTEMS DEVELOPMENT

B. Ramesh, Assistant Professor
Department of Systems Management

Sponsor and Funding: Naval Postgraduate School

OBJECTIVE: The objective of this research is to develop an environment to support various stakeholders involved in systems development by reasoning with design rationale knowledge.

SUMMARY: Large scale systems development and maintenance efforts are often hindered because much of the richness of the design process, namely the process knowledge, involving the deliberations on alternative design decisions is lost in the course of designing and changing such systems. We have developed a model that is geared towards capturing the rationales behind design decisions and using this knowledge to reason about changes in design decisions. The use of this model in software development based on knowledge based refinement paradigm was investigated. Use of the model for representation and reasoning with rationale behind formal specifications will greatly aid transformational development of systems based on formal specifications. A major objective of this research is to elevate the process of systems maintenance to the level of specifications and the rationale behind their creation. Further, a prototype environment to capture and reuse rationale to support various systems development activities is being developed.

PUBLICATIONS: Ramesh, B. and Luqi, "Process Knowledge Based Rapid Prototyping," in proceedings of the IEEE International Symposium on Requirements Engineering, San Diego,

CA, January 1993.

Ramesh, B. and Dhar, V., "Representation and Maintenance of Process Knowledge for Large Scale Systems Development," IEEE Expert, Special Series on Knowledge Based Software Engineering, accepted for publication.

THESES DIRECTED: Morris, Debra A., LT, USN and Paco, Tina M., LT, USN, "Towards an Information Model and Mechanisms for Design Rationale Capture and Use," Master's Thesis, September 1993.

Martinelli, Joseph, LT, USN, "An X11 Graphical Interface for the Representation and Maintenance of Process Knowledge (REMAP) Model," Masters's Thesis, September 1993.

Hughes, Frank, LCDR, USN and Kendall, Steven, CAPT, USMC, "An Implementation of the Representation and Maintenance of Process Knowledge (REMAP) Model in the Knowledge Based Software Assistant Concept Demonstration System," Master's Thesis, September 1993.

OTHER: The REMAP model and mechanisms developed in this research are being incorporated in the knowledge based software assistant CASE tool prototype being developed by the U.S. Air Force.

DOD KEY TECHNOLOGY AREA: Computers, Software, Design Automation.

KEYWORDS: Design Rationale, Process Knowledge, Systems Development.

COMPLEX TRACEABILITY TECHNIQUES FOR LARGE SCALE SYSTEMS

B. Ramesh, Assistant Professor

Department of Systems Management

**Sponsor and Funding: Naval Surface Warfare Center,
Dahlgren Division**

OBJECTIVE: The objective of this research is to develop a model of requirements traceability to support various stakeholders in large scale systems development.

SUMMARY: Development of complex, mission critical systems involves modification, refinement and evolution of initial requirements that lead to design solutions. In order to provide intelligent and useful support to the process of design and maintenance, a formal representation of the linkages between the design solutions and the requirements is essential. A comprehensive traceability scheme should not only identify traceability linkages to be maintained, but also provide the mechanisms to support use in systems development and maintenance activities. Based on an extensive empirical study of systems development personnel, this project has developed such a model for requirements traceability and identifies desired features in an ideal requirements traceability tool. Further, using a study of current practices, the issues in adopting a

comprehensive scheme of traceability are also highlighted.

PUBLICATIONS: Ramesh, B. and Edwards, M., "Issues in the Development of a Model for Requirements Traceability," in Proceedings of the IEEE International Symposium on Requirements Engineering, San Diego, CA, January 1993.

THESES DIRECTED: Powers, Timothy, LCDR, USCG and Stubbs, Curtis D., LT, USN, "A Study of Current Practices of Requirements Traceability in Systems Development, Master's Thesis, September 1993.

Harrington, Gale, Alicia, CPT, USA and Rondeau, Kathleen, Marie, LCDR, USN, "An Investigation of Requirements Traceability to Support Systems Development," Master's Thesis, September 1993.

DOD KEY TECHNOLOGY AREA: Computers, Software, Design Automation.

KEYWORDS: Requirements Traceability, Systems Development.

EVALUATION OF SECURITY COSTS INCURRED BY INDUSTRY
FOR FEDERAL GOVERNMENT CONTRACTS

J.G. San Miguel, Professor of Financial Management
Department of Systems Management

Sponsor and Funding: National Industrial Security Program
Washington, DC

OBJECTIVE: This field research at a sample of defense contractors gathered information from industry executives on the nature of security costs incurred on federal security requirements, the components of security costs, the accounting treatment for security costs, and the reporting of security costs. The work will continue as part of the Joint Security Commission's tasks.

SUMMARY: In cooperation with industry and government executives the National Industrial Security Program (NISP) was established to improve the efficiency and cost effectiveness of federal government security programs required of industry. As part of this undertaking there was a need to establish a baseline for costs being incurred by both industry and government security agencies, primarily the Department of Defense, the Department of Energy, and the Central Intelligence Agency. This research project pertains to the mission of the NISP Resources Working Group. This Working Group sought to determine the feasibility and the implementation of a periodic cost gathering procedure for industry's security organizations. The research methodology for this study consisted

of visits to a sample of companies that have varying security requirements and that are of different sizes. In addition, the security requirements are related to the three agencies, DoD, DoE, and CIA. Personal interviews were conducted at each individual site.

PUBLICATION: San Miguel, J.G., "Industrial Security Costs: An Analysis of Reporting Practices," NPS Technical Report, NPS-AS-93-020, August 1993.

THESIS DIRECTED: Matheny, P., LCDR, USN, "Resource Consequences of Altering the Delinquency Debt Threshold Used in Background Investigations for Security Costs," Master's Thesis, December 1993.

OTHER: Briefed the Joint Security Commission, Department of Defense and Director of Central Intelligence. The Commission was established in March 1993 as part of the Vice President Gore's Reinventing Government Program.

DOD KEY TECHNOLOGY AREA: Other.

KEYWORDS: Cost, Security, Allocation.

ACTIVITY BASED MANAGEMENT AND STRATEGIC PROFIT ANALYSIS

**J.G. San Miguel, Professor of Financial Management
Department of Systems Management**

**Sponsor and Funding: Activity Based Management Task Force,
American Institute of Certified Public Accountants**

OBJECTIVE: The aim of this research project is to develop a new approach to profit variance analysis that incorporates new theories concerning cost definitions, aggregation, and competitive analysis.

SUMMARY: Conventional cost-volume-profit analysis and profit variance analysis has been criticized because of the underlying cost behavior assumptions and unrealistic decision horizon. Given recent changes in cost definitions, cost disaggregation theories, and use of value added factors, a new framework is needed to meet the challenges of global competition and information technology. Activity based costing and, more recently, activity based management have provided new insights into cost analysis and decision making. In addition, the strategic implications of costs and competitors' actions are given explicit attention in decisions.

CONFERENCE PRESENTATION: San Miguel, J.G., "Activity Based Management's Potential Benefits," AICPA National Industry Conference, Dallas, TX, 30 April 1993.

OTHER: San Miguel, J.G. and J.K. Shank, "Activity Analysis Information for Management," Activity Based Management Task Force, American Institute of Certified Public Accountants, 24 February 1993.

CASES: Grand Jeans Company, July, 1993; Bridgewater Castings, Inc., (Revised) December 1992; Abrams Company, February 1993; Litton Industries, Inc., September 1993; Emerson Electric Company, revised December 1993.

DOD KEY TECHNOLOGY AREA: Other.

KEYWORDS: Strategy, Variance Analysis, Cost, Competitive Analysis.

A SOFTWARE RELIABILITY MODEL WITH OPTIMAL SELECTION OF FAILURE DATA AND A METHODOLOGY FOR APPLYING METRICS ON MULTIPLE PROJECTS

N.F. Schneidewind, Professor of Information Sciences

Department of Systems Management

Sponsor: Dr. William H. Farr, Code B-10, Naval Surface Warfare Center, Dahlgren, VA 22448

OBJECTIVES: (1) Develop enhancement to the Schneidewind software reliability model for determining the optimal length of failure history to use in the model; (2) Continue research on a methodology for applying metrics across multiple projects.

SUMMARY: (1) Research was conducted on the feasibility of optimally selecting failure data in order to identify the optimal set of model parameters that would result in maximum predictive accuracy, using the Schneidewind Software Reliability Model as a vehicle for the research. The research showed that significantly improved reliability predictions can be obtained by using a subset of the failure data, based on applying the appropriate criteria, and using the Space Shuttle On-Board software as an example. As a result of this research, an enhanced version of the Schneidewind model was implemented in the latest version of the NSWC SMERFS software reliability tool.

(2) A process was developed for applying metrics across multiple projects and a methodology was developed for assessing the risks of applying metrics on multiple projects.

PUBLICATIONS: Note: All of the following conference papers and tutorials were presented at the conference and tutorial.

Schneidewind, N.F., "Software Reliability Model with Optimal Selection of Failure Data," IEEE Transactions on Software Engineering, November 1993.

Schneidewind, N.F., "Experimental Designs for Validating Metrics and Applying them across Multiple Projects," Lecture Notes in Computer Science, 706, H. Dieter Rombach, Victor R. Basili, and Richard W. Selby, eds., Experimental Software Engineering Issues: Critical Assessment and Future Directions, International Workshop, Dagstuhl Castle, Germany, September 1992 in Proceedings, Springer-Verlag, pp. 216-220, 1993.

Schneidewind, N.F., "Report on the IEEE Standard for a Software Quality Metrics Methodology, IEEE Std 1061-1992," in Proceedings of the Conference on Software Maintenance '93, Montreal, Canada, pp. 104-106, 28 September 1993.

Schneidewind, N.F., Panel: "Standardization Issues in Software Reliability Engineering," (position statement), in Proceedings of the Software Engineering Standards Symposium, Brighton, UK, pp. 94-97, 2 September 1993.

Schneidewind, N.F., "Standardization of Software Reliability Estimation and Prediction: Application to Space Systems," in Proceedings of the Software Engineering Standards Symposium, Brighton, UK, pp. 164-166.1 September 1993.

Schneidewind, N.F., "Methodology for Software Quality Metrics," Software Engineering Standards Symposium, tutorial, Brighton, UK, 30 August 1993.

Schneidewind, N.F., "Optimal Selection of Failure Data for Predicting Failure Counts," in Proceedings of the 1993 Complex Systems Engineering Synthesis

and Assessment Technology Workshop,
Naval Surface Warfare Center, White Oak,
MD, pp. 141-157, 21 July 1993.

Schneidewind, N.F., "Software
Reliability Model with Optimal Selection
of Failure Data," in Proceedings of the
Fifteenth Minnowbrook Workshop on
Software Engineering, Blue Mountain
Lake, NY, pp. 180-199, 14 July 1993.

Schneidewind, N.F., "New Software-
Quality Metrics Methodology Standard
fills measurement need," IEEE Computer,
Vol. 26, No. 4, pp. 105-106, April 1993.

Schneidewind, N.F., Editor, IEEE
Standard for a Software Quality Metrics
Methodology, IEEE Std 1061-1992, 12
March 1993.

Schneidewind, N.F., "Software
Reliability Model with Optimal Selection
of Failure Data," in Proceedings of the
1993 Annual Oregon Workshop on Software
Metrics, 23 March 1993.

Schneidewind, N.F., "Validating and
Applying Software Metrics on Multiple
Projects," tutorial, DECollege, City
Hilton Hotel, Munich, Germany, 27
January 1993.

Schneidewind, N.F., "Applying
Reliability Models to the Maintenance of
Space Shuttle Software," in Proceedings
of the NASA/Goddard Software Engineering
Laboratory Seventeenth Annual Software
Engineering Workshop, Greenbelt, MD, pp.
286-292, 2 December 1992.

Schneidewind, N.F., Panel: "Reliability
Models and Metrics for Space Shuttle
Maintenance," (Position Statement), in
Proceedings of the Conference on
Software Maintenance - 1992, Orlando,
FL, p. 386, 12 November 1992.

Keller, T.W. and Schneidewind, N.F.,
"Applying Reliability Models to the
Maintenance of Space System Software,"
in Proceedings of the 1992 International

Simulation Technology Conference, pp.
273-278, Clear Lake, TX, 4-6 November
1992.

Schneidewind, Norman F., "Minimizing
Risks in Applying Metrics on Multiple
Projects," in Proceedings of the Third
International Symposium on Software
Reliability Engineering, Raleigh, NC,
pp. 173-182, 9 October 1992.

Schneidewind, N.F., Panel: "Collection
and Application of Software Quality
Data," in Proceedings of the Third
International Symposium on Software
Reliability Engineering, Raleigh, NC,
pp. 283-284, 9 October 1992.

Schneidewind, N.F., Panel on American
Institute of Aeronautics and
Astronautics Recommended Practice for
Software Reliability: Overview,
Proceedings of the Third International
Symposium on Software Reliability
Engineering, Raleigh, NC, pp. 124-125,
8 October 1992.

CONFERENCE AND COLLOQUIUM PRESENTATIONS:
Schneidewind, N.F., Panel: "Ten Years
of Software Maintenance: Progress or
Promises?" (position statement),
Conference on Software Maintenance '93,
Montreal, Canada, 30 September 1993.

Schneidewind, N.F., "Report on Workshop
on Software Measurement and Reliability
for Software Maintenance," Conference on
Software Maintenance '93, Montreal,
Canada, 29 September 1993.

Munson, J. and Schneidewind, N.F.,
"Software Measurement and Reliability
for Software Maintenance," Workshop held
in conjunction with Conference on
Software Maintenance '93, Montreal,
Canada, 26 September 1993.

Schneidewind, N.F., "Software
Reliability Model with Optimal Selection
of Failure Data," colloquium,
Laboratoire d'Automatique et d'Analyse

des Systems, Toulouse, France, 6 September 1993.

Schneidewind, N.F., "Do We Need Standards," Software Engineering Standards Symposium, Brighton, UK, 1 September 1993.

THESIS DIRECTED: Burton, Douglas R., LT, "Software Reliability Management Through Metrics," Master's Thesis, March 1993.

OTHER: A paper is in preparation to report on the latest results of this research that it is possible to apply metrics on large projects (Space Shuttle flight software) to control, predict, and assess software quality based on metrics collected during design. The approach was to validate metrics against a quality factor (discrepancy reports)

in accordance with the metrics validation methodology developed by the investigator and that is included in the IEEE Standard for a Software Quality Metrics Methodology (1061).

DOD KEY TECHNOLOGY AREA: Software.

KEYWORDS: Software Reliability, Software Quality Metrics.

LOCAL AREA NETWORK PERFORMANCE EVALUATION

N.F. Schneidewind, Professor of Information Sciences
Department of Systems Management
Sponsor: Unfunded

OBJECTIVE: Improve the prediction accuracy of a previously published Local Area Network (LAN) performance model.

SUMMARY: A previously published LAN performance model had two user response time components that involved transmission on the LAN: simultaneous input requests of N_u users for service from one of N_s servers transmitted over a broadband Ethernet; and transmission of the requested information over the Ethernet to the N_u user RAMs. The purpose of the model was to predict user response time under the condition of maximum stress on the LAN (i.e., when all users simultaneously request the same program). In the first implementation of the model, the Ethernet response time components were modelled by classical formulas. Although the model proved to be a good predictor of response time at light and moderate loads, it underestimated response time at high loads. The investigator developed a revised model to correct this deficiency with a novel way of providing a level of detail and accuracy (epochs of transmission, collision detection, backoff, and retransmission) that other analytic models of Ethernet performance do not provide.

PUBLICATION: Note: The following conference paper was presented at the conference.

Schneidewind, N.F., "An Ethernet Performance Model with N_u Users Simultaneously Accessing N_s Servers," in Proceedings of the Fourth Workshop on Future Trends of Distributed Computing Systems, Lisbon, Portugal, pp. 276-282, 23 September 1993.

CONFERENCE PRESENTATION: Schneidewind, N.F., "LAN Performance Models: Assumptions Versus Reality," ORSA/TIMS National Meeting, San Francisco, CA, 2 November 1992.

OTHER: Additional refinements of the model involving more accurate modeling of deferred transmission, collision detection, and retransmission are being developed.

DOD KEY TECHNOLOGY AREA: Communications Networking.

KEYWORDS: LAN Performance Model, Ethernet.

COALITION COMMAND AND CONTROL
S.D. Sessions, Senior Lecturer
C.R. Jones, Professor
Department of Systems Management
Sponsor and Funding: Institute For National Strategic Studies
National Defense University

OBJECTIVE: The objective of the research was to prepare a case for classroom discussion purposes in the war colleges and the National Defense University.

SUMMARY: A set of educational objectives were established to guide the case development and preparation functions. A library search, including theses on the subject, was conducted. The field work included interviews with senior military officers and high ranking civilians who had either been involved in humanitarian coalition activities or were knowledgeable about them. The

entire process was designed to involve military officers in the strategic aspects of coalition command and control with some attention devoted to the tactical ramifications of the subject. A final goal was to refine a person's decision making capabilities in terms of taking action under quite uncertain conditions.

DOD KEY TECHNOLOGY AREA: Human-System Interfaces.

KEYWORDS: Research, Publications, Faculty Activity Report.

INTEROPERABILITY

S.D. Sessions, Senior Lecturer

C.R. Jones, Professor

Department of Systems Management

**Sponsor and Funding: Institute For National Strategic Studies
National Defense University**

OBJECTIVE: The objective of the research was to prepare a case for classroom discussion purposes in the Advanced Management Program at National Defense University.

SUMMARY: A set of educational objectives were established to guide the case development and preparation functions. A library search, including theses on the subject, was conducted. The field work included interviews with senior military officers and high ranking civilians who had either been involved in the military actions of Desert Storm or were knowledgeable about them. The entire process was designed to involve executives in the strategic

aspects of interoperability with some attention devoted to the tactical ramifications of the subject. A final goal was to refine a person's decision making capabilities in terms of taking action under quite uncertain conditions.

PUBLICATION: Sessions, S.D. and Jones, C.R., "Interoperability-A Desert Storm Case Study," McNair Paper Eighteen, National Defense University, July 1993.

DOD KEY TECHNOLOGY AREA: Communications Networking, Electronic Devices, Human-system Interfaces.

KEYWORDS: Desert Storm, Decision making, Strategy.

BUMED PROJECT

D. Whipple, Chairman and Professor
R.T. Harris, Professor

Department of Systems Management

Sponsor and Funding: U.S. Navy, Bureau of Medicine and Surgery

OBJECTIVE: This multi-year project will develop, field-test, and implement a comprehensive Navy-wide executive management development program that will prepare selected Navy health care managers for executive positions in Navy MTFs

SUMMARY: In response to Congressional mandate and the concerns of top leaders in Navy Medicine about the adequacy of preparation of senior military health care professionals to successfully serve in top executive positions in MTFs, the Navy Surgeon General asked the Department of Systems Management of the Naval Postgraduate School to design a customized executive management development program that would effectively and efficiently satisfy the Navy's unique needs and constraints. As an initial step, NPS conducted a comprehensive needs assessment, based on 80 indepth interviews with senior Navy health care executives and a custom-designed questionnaire completed by 476 Navy health care managers. Each manager offered self-ratings on sixty-six management competencies. Several interesting and important differences were found between the different professional groups -- physicians, dentists, nurses, and allied health professionals, and administrators. The results of the needs assessment defined program content and have guided educational module design. A comprehensive program was devised and proposed to the sponsor in late 1993.

Thirty educational modules are under development and being field-tested at

Navy MTFs throughout CONUS. Each module is custom designed to respond to the unique aspects of Navy health care. Specialized materials, including case studies are being developed and tested. Feedback from participants of these module 'pilot-tests' has been consistently positive. In parallel with module field testing, NPS is evaluating available multi-media, video-teleconferencing technologies in anticipation of adopting and using such technology in distance learning elements of the program.

PUBLICATIONS: Roberts, B.J., Crawford, A.M., and Orloff, K.L., "Managing Navy Medical Treatment Facilities: The Role of Executive Education," Navy Medicine, pp. 19-23, Sep-Oct 1993.

Crawford, A.M, Roberts, B.J., and Orloff, K.L., "A Preliminary Analysis of Educational Needs for Navy Health Care Executives," NPS Technical Report, NPS-AS-93-016, August 1993.

THESES DIRECTED: Dyson, Mari K., LT, USN, "Tri-Service Coordinated Care (TRICARE): A Study of Change Management," Master's Thesis, December 1993.

Morrison, John R., LT, MSC, USN, "The Relationship Between the Perceived Executive Management Capabilities of Senior Navy Medical Department Executives and Their Reported Managerial Requirements," Master's Thesis, June 1993.

Nerio, Guillermo, Jr., CPT, USMC and O'Connor, Richard B (II), CPT, USA, "TRICARE: An Organizational Change Study in the Military Health Services

System," Master's Thesis, December 1993.

Newton, Mary Beth, LCDR, USN, "Effective Leadership Through Empowerment: A Case Study," Master's Thesis, June 1993.

Nixon, Cynthia A., LT, MSC, USN, "Improving Hospital Productivity: An Analysis of the Contribution of Administrative/Clerical Staff to Physician Productivity," Master's Thesis, June 1993.

Schachman, Alan, Jr., CPT, USMC, "An Examination of Current Navy Medical Professionals Management Oriented Service Short Courses," Master's Thesis, June 1993.

DOD KEY TECHNOLOGY AREA: Other.

KEYWORDS: Executive Education, Managed Care, Management Development, TRICARE, Medical Professionals, Military Health Care, Executive Competencies.

**DEPARTMENT
OF
SYSTEMS MANAGEMENT**

**1993
Faculty Publications
and Presentations**

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Abdel-Hamid, T.K., Sengupta, K., and Ronan, D., "Software Project Control: An Experimental Investigation of Judgment with Fallible Information," IEEE Transactions on Software Engineering, June 1993.

Abdel-Hamid, T.K., "Thinking in Circles," American Programmer, May 1993.

Abdel-Hamid, T.K., "Adapting, Correcting, and Perfecting Software Estimates: A Maintenance Metaphor," Computer, March 1993.

Bhargava, H. and Kimbrough, S.O., "Model Management: An Embedded Languages Approach," Decision Support Systems, Vol. 10, No.3, pp. 277-300, 1993.

Bhargava, H., "Dimensional Analysis in Mathematical Modeling Systems: A Simple Numerical Method," ORSA Journal on Computing, Vol. 5, No. 1, pp. 33-39, 1993.

Bhargava, H. and Krishnan, R., "Computer-Aided Model Construction," Decision Support Systems, Vol. 9, No. 1, pp. 91-111, 1993.

Gonzales, R., Means, T., and Mehay, S., "Empirical Tests of the Samuelsonian Publicness Parameter: Has the Right Hypothesis Been Tested?" Public Choice, Vol. 77, No. 3, pp. 523-534, November 1993.

Haga, W.J. and Zviran, M., "Key Issues in IS Management: U.S. DoD Perspective," in Defense Analysis, Vol. 9, No. 2, pp. 197-210, August 1993.

Lamm, D.V. and Pursch, W.C., "A Dictionary of Contracting Terms, Part III," Contract Management, Vol. 33, No. 4, pp. 16-21, April 1993.

McCaffery, J.L. and Doyle, R., "The Budget Enforcement Act in 1992: Necessary But Not Sufficient," Public Budgeting and Finance, Vol. 13, No. 2, pp. 20-37, Summer 1993.

McCaffery, J.L., "Symposium on Federal Financial Management Reform. Introduction: Part II," Public Budgeting and Finance, Vol. 13, No. 1., pp. 59-60, Spring 1993.

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Park, J. and K. Kang, "Delay Analysis for Multidimensional Queueing Process in CSMA/CD Area Network," Telecommunications Management, Vol. 1, pp. 217-242, 1993.

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Terasawa, K.L. and Gates, W.R., "Burden Sharing In the Persian Gulf: Lessons Learned and Implications for the Future," Defense Analysis, Vol. 9, No. 2, Summer 1993.

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Haga, W.J. and Harrigan, J.D., "Protecting Information Systems in Natural Disasters: U.S. DoD Experience," in Proceedings of the Computer Security Conference International '93, pp. 483-489, London, October 1993.

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Ramesh, B. and Edwards, M., "Issues in the Development of a Model for Requirements Traceability," in Proceedings of the IEEE International Symposium on Requirements Engineering, San Diego, CA, January 1993.

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Bradley, R. and Roberts, N.C., "Relations of Affect and Control and Organizational Function," Academy of Management Meeting, Atlanta, GA, 6-11 August 1993.

Eitelberg, M.J., "The All-Volunteer Force after Twenty Years," A Military of Volunteers: Yesterday, Today, and Tomorrow, a conference commemorating the twentieth anniversary of the All-Volunteer Force, U.S. Naval Academy, Annapolis, MD, September 1993.

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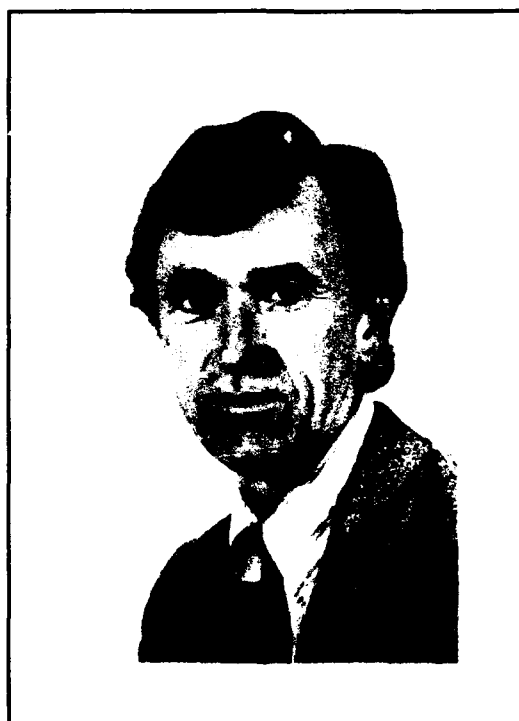
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ELECTRONIC WARFARE ACADEMIC GROUP



Jeffrey B. Knorr
Chairman

ELECTRONIC WARFARE ACADEMIC GROUP

The Electronic Warfare Academic Group (EWAG) is an interdisciplinary group of faculty who hold appointments in the eleven Departments at the Naval Postgraduate School. These faculty members are responsible for guidance of the electronic warfare curricula for U.S. and International students. Their participation in the EWAG is voluntary and is a result of their interest in applying their expertise to problems related to electronic combat.

Most EWAG faculty do some research related to electronic warfare. The primary purpose of this summary is to provide an overview of their work. In addition, there are a few faculty who do EW research and who are not presently EWAG members. They are included here, as well, in order to provide a comprehensive overview of NPS faculty participation in support of electronic warfare.

The research summaries and publication lists of the EWAG faculty are not included in this section. Since all EWAG faculty hold appointments in a Department, their summaries and publications appear there.

During 1993, the membership of the Electronic Warfare Academic Group was as follows:

- Prof. Michael Bailey (OR)
- Prof. Alfred Cooper (PH)
- Prof. Kenneth Davidson (MR)
- CDR Rick Erazo (3A), Curriculum Officer
- LCDR Danny Farley (32)
- Prof. Wayne Hughes (OR)
- Prof. David Jenn (EC), Academic Associate
- Prof. Jeffrey Knorr (EW), Acting Chairman
- Prof. Fred Levien (EC)
- Prof. Michael Morgan (EC)
- Prof. Phillip Pace (EC)
- Prof. Ron Pieper (EC)
- Prof. Arthur Schoenstadt (MA)
- Prof. Joseph Sternberg (PH)
- Prof. Harold Titus (EC)

The following faculty, although not on the 1993 EWAG, had research programs which contributed to the success of the electronic warfare program:

- Prof. Richard Adler
- Prof. Herschel Loomis

An overview of the Electronic Warfare Academic Group research program follows below:

RESOURCE ALLOCATION

Prof. Mike Bailey (OR), began a new project to develop a simulation model capable of assisting the Coast Guard with decisions concerning USCG resource allocation, resource scheduling, and tactics. The work resulted in a presentation by two of Prof. Bailey's students at the National Meeting of the Operations Research Society of America and the Institute of Management Science, 16-19 May 1993.

INFRARED SEARCH AND TARGET DESIGNATION

Prof. Alf Cooper continued with three research programs carried out in the Naval Academic Center for Infrared Technology (NACIT); Infrared Search and Target Designation, Strike Warfare Support, and FLIR Performance Prediction Code Validation. This work resulted in three theses and acceptance of two papers for presentation at the 1994 SPIE Conference. In addition, a new project, Infrared Technology Support to the AEGIS Program, was completed. This project resulted in one paper accepted for presentation at the 1994 SPIE Conference and three technotes which will appear later as NPS technical reports. Participating in these projects with Prof. Cooper were Profs. Crittenden, Milne, Pieper and Research Associates Lentz and Walker.

ATMOSPHERIC STUDIES

Prof. Ken Davidson participated in seven projects involving atmospheric research of importance in predicting propagation effects impacting the performance of radios and radars. These projects resulted in four theses, 12 conference publications, and one technical report. Also participating in these projects with Prof. Davidson were Prof. Wash and Research Associates Guest, Frederickson, Jones and Lind.

RCS AND SCATTERING STUDIES

Prof. Dave Jenn worked on the enhancement of a set of radar cross section and radome analysis codes. These codes were developed during an earlier phase of this project and have been delivered to several Navy labs as well as private contractors. These codes are useful for low observable studies and for determining the defocusing and depolarization effects of curved radomes. The codes were tested and verified. This work resulted in two theses, three conference presentations, and one IEEE journal publication.

COUNTERMEASURES

Prof. Fred Levien directed several countermeasures studies. One of these addressed laser guided surface-to-air missile (SAM) countermeasures and another, countermeasures against advanced laser beamrider SAMS. A third study dealt with countermeasures against missiles with seekers operating in the visible portion of the spectrum. Another study resulted in development of an EA-6B jamming algorithm for upgrade of the Air Force Improved Many-On-Many (IMOM) EW Mission

Planning System. This allows the system to now be used jointly by both Navy and Air Force planners. Another study was carried out to investigate transportability issues relative to unintentional modulation-on-pulse emitter data among Navy ESM processors. Five theses were directed, one on each of the above studies.

FIELD CANCELLATION

Prof. Mike Morgan initiated a two year project to investigate a practical approach for reducing bistatic radar cross section using active cancellation. Numerical simulation results obtained during 1993, show at least 20 dB reduction of bistatic RCS over all aspects around frequencies corresponding to canceller spacings of one-fourth wavelength. Reductions of 30-40 dB are observed at lower frequencies. A paper is being prepared on these results.

ANTI-SHIPING COUNTERMEASURES

Prof. Phillip Pace initiated a project to improve the process for evaluating hardware-in-the-loop and field test performance results for anti-shiping missiles operating in an ECM environment. New ECM effectiveness algorithms have been developed and seeker characterization has been improved in the initial phase of this project.

Prof. Pace also initiated a project to experimentally investigate the trade-offs between two Phalanx search signal processing schemes to detect low-velocity surface threats. Using actual, coherently recorded sea clutter data, both an inverse MTI approach and a narrowband filtering approach were optimized and evaluated. The results of this research are being used to construct a new surface-mode processor for the Phalanx RF sensor upgrade. This work resulted in one journal publication, a technical report, a conference presentation, and two theses.

IR PASSIVE RANGING AND IR THERMAL IMAGING

Prof. Ron Pieper initiated a project to investigate both experimental and computer modeling for determining passive range and other features based on IR measurements. A method based on triangulation was investigated. The sensitivity of the range prediction to variation in the bearing accuracy was evaluated in terms of the distance between baselines, target orientation, and range to the target. The dual baseline system was shown to have significant tactical advantages over a single baseline system. This work resulted in one thesis and a technote. A paper presenting the results of this work is being prepared in collaboration with Prof. Alf Cooper.

Prof. Pieper has also been collaborating with Prof. Alf Cooper on a new model for predicting MRTD performance of thermal imaging systems. Because the new model makes no explicit assumption regarding the nature of the testing process, it provides an excellent framework for automated or objective MRTD predictions. Tests with the proposed model have shown improved modeling in domains where the currently accepted models have been less reliable. The results obtained by

applying this model on the common module parallel scanning FLIR have appeared in a recent SPIE article. Extensions of this model to cover the thermal imaging systems which employ focal plane array technology is in development.

METHODOLOGY FOR C3I

Prof. Joe Sternberg continued work on his project, "A New Methodology for Supporting C3I Requirements". The objective of this project is to develop and exercise a new methodology for assessing the contribution of non-organic sensor information on the effectiveness of a battle force. The key element of the methodology is a unique wargame in which the non-organic information can be treated as the experimental variable affecting the tactical choices made by the commanders. The methodology has been adapted to contingency operations including strikes ashore and anti-air warfare in a littoral environment. The modifications to the game support software package have been tested and perform to current specifications. A full system test, using officers with carrier battle group experience as players, is in the planning stage. Following any further modifications resulting from the test program, the methodology will be applied to a selected real-world problem. Prof. Sternberg was assisted on the project by R. Thackeray.

MISSILE SIMULATION/TARGET LOCATION

Prof. Hal Titus continued his work with the Crossbow Committee and several of their intelligence teams. He has developed detailed simulations of several missile systems as a means of studying their guidance and control systems and developing possible counter-measures. The work involved several thesis students. Prof. Titus also conducted a second project which addressed the problem of locating targets from space platforms. Algorithms were developed to FFT process and Kalman filter observable signal parameters to locate targets of interest. This project resulted in several theses and one conference presentation.

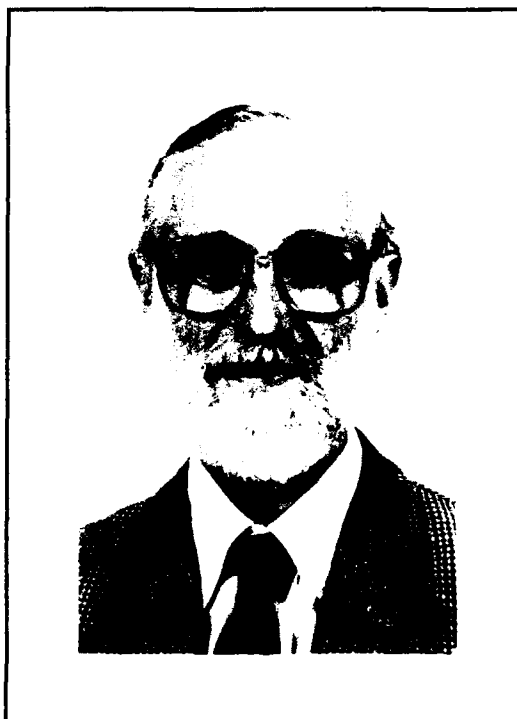
SIGINT/COMMUNICATION SYSTEM PERFORMANCE EVALUATION

Prof. Dick Adler continued ongoing projects to improve the operational performance of Army and Navy SIGINT systems. The work involved identifying radio noise sources as well as predicting the signal environment. This work resulted in nine conference publications, five theses, and four technical reports. Another project to evaluate communication system performance and high latitude propagation was also continued. The goal of this project was to conduct numerical analysis and experimental research in support of the Navy's requirement to site communication systems in polar and equatorial regions in rugged terrain. This work resulted in 1 conference presentation, 2 theses, and four technical reports. Prof. Adler was assisted on these projects by W. Vincent and D. Wadsworth.

LPI INTERCEPT/TACTICAL DISPLAY

Prof. Hersch Loomis continued several research thrusts. One project involved algorithms and architectures for processing tactical information and the other involved advanced algorithms and architectures for the detection and characterization of broadband communications signals in noise and interference. This work resulted in two conference presentations, one journal publication, and four theses. Prof. Loomis was assisted on these projects by R. Bernstein and M. Soderstrand.

SPACE SYSTEMS ACADEMIC GROUP



Rudolf Panholzer
Chairman

SPACE SYSTEMS ACADEMIC GROUP

The Space Systems Academic Group (SSAG) is an interdisciplinary association providing direction and guidance for the Space Systems Engineering and Space Systems Operations curricula. SSAG relies on faculty and facilities support from the departments of Aeronautical and Astronautical Engineering, Computer Science, Electrical and Computer Engineering, Mathematics, Mechanical Engineering, Meteorology, Oceanography, Operations Research, Physics, and Systems Management.

The mission of the Space Systems Academic Group (SSAG) is to provide space systems officer students practical learning opportunities via hardware-based theses and experience tours to supply our sponsors with adequate numbers of space-qualified military personnel; and to develop the Naval Postgraduate School's Space Systems Engineering and Space Systems Operations academic curricula programs.

On-going projects within SSAG provide a space-hardware-oriented environment ideal for students to gain experience in design, development, installation, system integration, and maintenance of spacecraft and payloads. Officer students are exposed to space related research projects as well as formal classroom instruction, and are required to complete a space-oriented thesis for the Master of Science degree requirements.

In the 1993 academic year, officer students in the Space Systems Curricula and participating faculty from several departments were engaged in four major areas of space research and development: (1) Spacecraft Technology; (2) Satellite Communications; (3) Acoustics in Space; (4) Space Environment; and (5) Computer Memory Technology in Space. In addition (6), SSAG assisted participating departments in the continuing development of several Spacecraft and Flight Hardware Laboratories and Support Facilities.

SPACECRAFT TECHNOLOGY

Small Satellite Design Studies (PANSAT)

Directed by Professor Rudolf Panholzer, the Small Satellite Design Studies program is part of the Spacecraft Technology research effort incorporating proven and 'leading edge' technology in a hardware project.

The Small Satellite Design Studies originated with the ORION Mini-Satellite Program, a prototype general purpose satellite. The continuing project is the Petite Amateur Navy Satellite (PANSAT) which will investigate spread spectrum communication with store-and-dump capability for relaying information digitally.

The PANSAT research project will involve officer students in the design, fabrication and integration of a 150 lb. satellite dedicated to function as a small packet radio communications satellite using spread spectrum techniques. PANSAT will serve as a quick-reaction, low-cost, direct-sequence spread spectrum packet communication satellite, and will provide a low-cost space-based platform

for small experiments. Since spread spectrum modulation provides low-probability-of-detection and low-susceptibility-to-jamming, PANSAT can quickly increase defense communication systems in times of crisis.

The PANSAT satellite was originally presented at the 3rd Annual AIAA/Utah State University Conference on Small Satellites, 26-28 September 1989. An update was presented at the 4th Annual AIAA/Utah State University Conference on Small Satellites, 28-31 September 1993, and at the AIAA Space Programs and Technologies Conference and Exhibit, 21-23 October 1993, Huntsville. A flight request was submitted to the Space Test Program on 30 December 1993.

A Study of the Temperature History of PANSAT Over a Single Orbit

Professor Allan D. Kraus modeled the Petite Amateur Navy Satellite (PANSAT) both for steady state and transient thermal analysis. The scientific objective of his research was to determine the temperature history of the PANSAT vehicle over a single orbit. Using an existing computer code to determine the single-orbit temperature pattern for PANSAT, Professor Kraus approximated the extremes of temperature for both sunlight and shadow zones. (See Department of Electrical and Computer Engineering.)

SATELLITE COMMUNICATIONS

PANSAT Communications System Design

Under professors Tri Ha's guidance, the effort of three research theses were directed to design and build a breadboard direct sequence spread spectrum transceiver for the Petite Amateur Navy Satellite (PANSAT). (See Department of Electrical and Computer Engineering.)

ACOUSTICS IN SPACE

Thermoacoustic Life Sciences Refrigerator (TALSR)

Professor Steve L. Garrett's team designed a thermoacoustic refrigeration system for use on-board the Space Shuttle to provide cooling for biological samples.

TALSR provided thesis research topics for graduate students in a broad range of areas in mechanical and electrical engineering, physics, and engineering acoustics involving thermodynamics, heat transfer, analog and digital electronic control, structural analysis, and transduction.

Since TALSR has commercial applications as a potential replacement for CFC-based home refrigerator/ freezers, a Co-operative Research and Development Agreement (CRADA) was established involving NASA and General Electric Government Services. Thus students were also exposed to issues associated with dual-use (military/commercial) technologies and to the process of technology transfer. (See Department of Physics.)

Thermoacoustic Refrigerator (TAR III) Designs for Space

Professor Thomas J. Hoffer continued research and development efforts to design, fabricate, and space-qualify the third generation of Thermoacoustic refrigerators (TAR III) suitable for use in spacecraft, for the purpose of cooling electronics and sensors to cryogenic temperatures. The goal of this ongoing research is to improve the refrigerator performance and design on both a fundamental and on a practical level. (See Department of Physics.)

SPACE ENVIRONMENT

Space Power Experiment Aboard Rocket (SPEAR)

Professor R.C. Olsen continued work on the space power experiment to support the SPEAR III design phase. In particular, to advise on the charging behavior experienced in SPEAR I, and on flight instrumentation for the new mission. The rocket was successfully launched on 15 March 1993. (See Department of Physics.)

Equatorially Trapped Plasmas

Professor R.C. Olsen continued his studies of the nature of equatorially trapped plasmas, and the interaction between such plasmas and the magnetosphere filling problem. He analyzed data from the AMPTE/CCE and Los Alamos 1989-046 satellite and conducted several surveys. The most intriguing element discovered to date is a link between the ionospheric photoelectron flows and the equatorially trapped electrons. (See Department of Physics.)

Remote Sensing of The Ionospheric E- and F-Layers

The sounding rocket experiment for remote sensing of the ionosphere conducted by Prof. David Cleary is continuing. The object of this ongoing research project is to develop a simple technique for measuring global ionospheric electron densities from a space based platform. The short term goal of this project was to obtain ultraviolet spectra of the Earth's ionospheric day glow. The long term objective is to identify ultraviolet atmospheric emissions that can be used to infer electron density profiles with the aid of photochemical and radiative transfer models. The second MUSTANG/HIRAAS experiment was successfully flown on March 1992. UV spectra of the Earth's ionosphere were obtained between 100 and 320 km on both the upleg and downleg portions of the flight. The electron density predicted from these rocket observations will be compared with ground based measurements of the electron density profile. (See Department of Physics.)

On-Orbit Annealing of Satellite Solar Panels

Professor Sherif Michael continued research on photo voltaic power technology by investigating the possibility to anneal a satellite's InP and GaAs solar cells while in orbit using new minority carriers annealing techniques. Research tasks included the development and completion of the Solar and Radiation Laboratory, the development of the microprocessor based Photo voltaic experiment as well as testing of the solar panels for the PANSAT satellite. (See Department of Electrical and Computer Engineering.)

COMPUTER MEMORY TECHNOLOGY IN SPACE

Ferroelectric Technology

Professor Panholzer's team continued research on Computer Memory Technology in Space to evaluate ferroelectric technology for its suitability in military and space applications.

Under Professor Panholzer's direction, a Thin-Film Ferroelectric Experiment (NPS FERRO-001) was designed to test the effects of space environment on aging and fatiguing characteristics of ferroelectric capacitors. This research is expected to continue into 1994.

SPACECRAFT AND FLIGHT HARDWARE LABORATORIES/FACILITIES

The Space Systems Academic Group (Code SP) and participating departments have continued to dedicate both labor and material resources to the development of several laboratories and support facilities:

- (SP01) Spacecraft Integration & Test (SP);
- (SP02) Open Site EMI/EMC (SP);
- (SP03) Satellite ground Station (SP);
- (SP04) AIS Computing (SP);
- (SP05) Precision Fabrication Facility (SP);
- (AA17) FLTSATCOM Satellite Operation, Sim. & Test (SP/AA);
- (AA18) Spacecraft Attitude Dynamics & Control (SP/AA); and
- (AA19) Spacecraft Environmental Simulation & Test (SP/AA).

SMALL SATELLITE DESIGN STUDIES (PANSAT)

R. Panholzer, Professor and Chairman
Space Systems Academic Group
Sponsor and Funding: Naval Research Laboratory,
Army Space Technology Research Office,
and Naval Postgraduate School

OBJECTIVE: The goals of the Continuing Small Satellite Design Studies program are (1) to enhance education of officer students through a systems engineering approach; (2) to design, fabricate, test, and ultimately launch a small satellite for operation by NPS; (3) to demonstrate the feasibility of small satellites for supporting defense needs; and (4) to provide a valuable space asset to augment existing military communications.

SUMMARY: In the 1993 academic year, the PANSAT research project progressed beyond feasibility studies to detailed designs of the communications payload and the supporting electronic subsystems. The functional requirements of the spacecraft were also updated to reflect the findings of work completed. The following major changes to the spacecraft design were implemented: (1) provided simplex operation rather than duplex; (2) increased the data rate to accommodate simplex operation; (3) reduced the number of processors to a redundant pair; and (4) changed the frequency allocation initially requested. Specific subsystem tasks completed during the CY 93 period:

(1) Computer. The design was modified to cover control of the entire spacecraft with an identical computer system for redundancy. The design has been developed including parts which have been ordered for breadboard and testing.

(2) Communication Payload. Working breadboards were developed utilizing easily obtainable parts for a spread spectrum receiver/transmitter using both binary-phase-shift-keying (BPSK) and 4-frequency-shift-keying modulation schemes. A BPSK modulation scheme was selected and design continues for bread boarding the communication subsystem utilizing parts with functional equivalent specifications. This, however, may force a long lead time for delivery of components. A revised link budget was performed and modification was included due to the change to simplex operation and higher transmission rate.

(3) Electric Power. The power budget for the spacecraft was recalculated utilizing the inputs from the other electronic subsystems. A design was developed which will utilize solar cells, 2 Nickel-Cadmium batteries, battery charge regulator, and power conditioning to provide ± 15 Volts and ± 5 Volts to the various electronics on-board. A test plan was developed for qualification and acceptance of the flight panels/cells.

(4) System Design. Work was completed in configuration of the spacecraft and its subsystems. This includes placement of subsystems, mass characteristics, and engineering drawings. Additionally, work was done in preparing documentation for test plans, interface control, and on-orbit operations.

THESES DIRECTED: Ashe, John D., LT, USN, "Petite Amateur Navy Satellite Spacecraft Digital Control System: A Hardware Design," Master's Thesis, March 1993.

Murray, Terrence J., LT, USN, "Four Frequency-Shift Keying (4-FSK) Spread Spectrum Modulator and Demodulator," Master's Thesis, March 1993.

Brown, Arnold O., LT, USN, "Communication Subsystem for the Petite Amateur Navy Satellite (PANSAT)," Master's Thesis, September 1993.

DOD KEY TECHNOLOGY AREA:
Environmental Effects, Design Automation.

KEYWORDS: Satellite, Spacecraft Design.

THIN-FILM FERROELECTRIC EXPERIMENT (FERRO NPS-001)

R. Panholzer, Professor and Chairman
Space Systems Academic Group
Sponsor and Funding: Naval Research Laboratory
and Naval Postgraduate School

OBJECTIVE: The NPS research program on Computer Memory Technology in Space has as its objectives: (1) to enhance the education of officer students in the Space Systems Curricula; (2) to provide a cost-efficient experiment to test the space-related characteristics of ferroelectric capacitors and other devices; and (3) to contribute to the military efforts to evaluate ferroelectric materials to determine if the technology holds promise. The Thin-Film Ferroelectric Experiment (FERRO NPS-001) is the current continuing project of the Computer Memory Technology in Space Research Program. The goal of the on-going thin-film ferroelectric memory research project is to evaluate ferroelectric technology to determine its suitability in military and space memory applications.

SUMMARY: NPS-001 FERRO is a thin-film ferroelectric experiment manifested on the Advanced Photo voltaic and Electronics Experiment (APEX) satellite manufactured by Orbital Sciences Corporation (OSC) of Fairfax, VA. It will test the effects of space environment (most importantly radiation) on aging and fatiguing characteristics of ferroelectric capacitors. That is, thin-film capacitors will be tested for their ability to store and retain data in space.

The FERRO NPS-001 experiment will test the effects of space environment (most importantly radiation) on aging and fatiguing characteristics of ferroelectric capacitors--they will be tested for their ability to store

and retain data in space. One flight aboard the Pegasus launch vehicle (Pegastar Bus) has been scheduled for June 1994. Resulting data will help determine in what ways ferroelectrics can replace memory technology in military space applications.

Progress to Date:

Methodology. On-ground and on-orbit fatigue, aging and radiation testing procedures have been established using: (a) irradiated materials and devices for on-ground tests, and (b) high radiation orbits for space environment tests (NPS-001).

On-ground Testing. A radiation-fatigue test board was designed to allow accurate and simultaneous testing of multiple ferroelectric devices; and experiment level environmental tests were performed in CY93 by SSAG staff engineers.

On-orbit Testing. Procedures have been devised to test ferroelectric capacitors as they are flown in a high radiation orbit. The electronic hardware design for the NPS-001 experiment is complete. The experiment housing fabrication has been completed. Environmental tests and thermal analysis have been performed. The experiment control software, and data reduction software will be developed in CY 1994.

DOD KEY TECHNOLOGY AREA:
Environmental Effects, Design
Automation.

KEYWORDS: Ferroelectrics, Memory
Technology.

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